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IDENTIFIERS	*Coal Mining; Solid State Electrical Systems

ABSTRACT

Twenty-one competency based instructional units are included in this solid-state electrical controls curriculum which is designed to upgrade the skills of coal mine electricians who work with mining equipment that has solid-state electrical controls. Each unit contains one or more student competency sheets with necessary attachments or handouts, study questions, experiments, troubleshooting problems, and criterion referenced tests. A program pretest and general student directions precede the instructional units. A teacher's guide accompanies this document under separate cover. (BM)

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ED150335

STUDENT CURRICULUM
"UPGRADING MINE ELECTRICIANS IN THE USE OF SOLID STATE ELECTRICAL CONTROLS"

Prepared by:
West Virginia Department of Education
Bureau of Vocational, Technical and
Adult Education

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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CE 014 541

September 30, 1977

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Contract No. OEG-G007603756.

PREFACE

It is with the greatest pleasure that we bring you another West Virginia competency based education (CBE) curriculum. The curriculum for "Upgrading Mine Electricians in the Use of Solid-State Electrical Controls" has been developed during July 1, 1976 - June 30, 1977 by:

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S & S Corporation
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West Virginia Coal Mining Advisory Council

Amherst Coal Company
Logan County Board of Education
U. S. Steel Corporation
Consolidated Coal Company
Carbon Fuel Company
Department of Employment Security

Island Creek Coal Company
Eastern Associated Coal Corp.
Westmoreland Coal Company
Pittston Coal Company
Cannelton Industries
West Virginia Coal Association

The Bureau of Vocational, Technical and Adult Education, State Department of Education, began advocating CBE curriculum in 1974. Since that time we have produced state CBE curricula in a number of additional occupational areas. We also have a number of CBE curricula currently in the process of being developed and/or field-tested.

I trust this Solid State Electronics curriculum will help your program. Any suggestions you may have for improving this curriculum may be sent to the curriculum lab. Through this and other feedback we plan to continually update our curriculum. Additional copies of this curriculum are available at the Vocational Curriculum Laboratory, Cedar Lakes Conference Center, Ripley, West Virginia, 25271.

Clarence Burdette
Assistant State Superintendent of Schools
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Adult Education

Introduction to Competency Based Education (CBE) and How to Use the Course Materials

This talk will introduce you to Competency Based Education or CBE and it will explain how to use the course materials. You should have a packet of written material called Unit 01: meters, Part I. As you listen to the tape, look at and read the written material when you are told to do so. If you have any questions or problems, ask the instructor to stop the tape and help you out.

Look at the top sheet of the packet that you have. The first thing on that sheet is Unit 01: meters, Part I. The whole course is divided up into Unit Packets and each has a number and a title. This unit deals with meters. It is part one of several units dealing with meters. Whenever the unit title says Part I there will always be a Part II and sometimes a Part III. Knowing this will help you keep the units in order. This first sheet is called Student Competency Sheet #1. The first sheet of every unit will be a student competency sheet. This will tell you what is expected of you and what to do for each unit. Right now we will explain what is on the student competency sheet and how to use it.

Look at the section called "Competency Statement" on Student Competency Sheet #1. Read it. (pause) "Competency Statement: Identifies the general characteristics of the multimeter (VOM)

AND USES THE MULTIMETER (VOM) AS AN OHMMETER TO CHECK RESISTANCE." THIS TELLS YOU WHAT A COMPETENT ELECTRICIAN DOES. THE AIM OF THIS COURSE IS TO HELP YOU BECOME COMPETENT IN WORKING WITH SOLID STATE EQUIPMENT. SOMEONE WHO WORKS WITH SOLID STATE EQUIPMENT SHOULD BE ABLE TO DO WHAT THE COMPETENCY STATEMENT SAYS. READ IT AGAIN. (PAUSE) MAYBE YOU KNOW HOW TO DO THIS ALREADY, BUT MAYBE SOME OF YOU DON'T KNOW OR AREN'T SURE. FOR NOW, JUST REMEMBER THAT WHENEVER YOU READ A COMPETENCY STATEMENT IT DESCRIBES WHAT A COMPETENT ELECTRICIAN DOES AT WORK. THIS IS WHY THIS APPROACH IS CALLED COMPETENCY-BASED EDUCATION. IT STARTS EACH UNIT BY TELLING YOU WHAT A COMPETENT ELECTRICIAN DOES. THIS COMPETENCY STATEMENT IS BASIC, BUT EACH ONE WILL GET HARDER AS YOU MOVE ALONG IN THE COURSE.

(PAUSE)

ON YOUR STUDENT COMPETENCY SHEET #1 FIND THE SECTION CALLED "PERFORMANCE OBJECTIVE" AND READ IT. (PAUSE)

"PERFORMANCE OBJECTIVE

ACTION: YOU WILL USE THE MULTIMETER TO MEASURE RESISTANCE AND ANSWER QUESTIONS ABOUT ITS USE.

CONDITIONS: YOU HAVE 10 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARDS: ALL YOUR ANSWERS MUST BE CORRECT. ALL READINGS

MUST BE WITHIN 20% OF THE ACTUAL RESISTANCE VALUE."

YOU WILL NOTICE THAT THE PART CALLED "ACTION" IS ALMOST THE SAME AS THE "COMPETENCY STATEMENT." THE MAIN DIFFERENCE IS THAT THIS TIME YOU ARE TOLD WHAT TO DO. YOU HAVE TO ANSWER QUESTIONS AND MEASURE RESISTANCE. NOW LOOK AT THE PART CALLED "CONDITIONS." THIS TELLS YOU TO DO THIS IN 10 MINUTES AND NOT TO USE ANY REFERENCES. IN OTHER WORDS, THE "ACTION" PART TELLS YOU WHAT TO DO AND THE "CONDITIONS" PART TELLS YOU UNDER WHAT CONDITIONS TO DO IT. WHEN YOU LOOK AT THE "STANDARDS" PART, YOU SEE HOW THE INSTRUCTOR WILL SCORE YOUR PERFORMANCE. THE ENTIRE "PERFORMANCE OBJECTIVE" TELLS YOU WHAT TO DO TO DEMONSTRATE COMPETENCE. WHEN YOU THINK YOU CAN DO THIS, YOU SHOULD ASK THE INSTRUCTOR TO GIVE THE EXAMINATION TO YOU. THE INSTRUCTOR WILL TELL YOU WHETHER YOU HAVE DONE THE "PERFORMANCE OBJECTIVE" CORRECTLY OR NOT. REMEMBER, TO DO THE "PERFORMANCE OBJECTIVE" YOU MUST DO THE ACTION UNDER THE CONDITIONS AND UP TO THE STANDARD. WHEN YOU CAN DO THIS, YOU MOVE ON TO THE NEXT UNIT.

(PAUSE)

LET'S GO BACK AND REVIEW. GO BACK AND READ THE "COMPETENCY STATEMENT" AND THE "PERFORMANCE OBJECTIVE" FOR THE FIRST UNIT. (PAUSE) THE "COMPETENCY STATEMENT" TELLS YOU WHAT A COMPETENT ELECTRICIAN DOES. THE "PERFORMANCE OBJECTIVE" TELLS YOU WHAT YOU MUST DO TO SHOW THAT YOU ARE COMPETENT IN DOING THIS. THE instructor has the exam questions for you to answer. You will not see these until you say you are ready to take the exam. Every time you get a new unit packet, read the "Competency Statement" and the "Performance Objective." This will tell you what is expected of you and what you are supposed to do. Don't worry if you can't do this or are not sure. The rest of the packet will help you do this.

(Pause)

Suppose that you read the Performance Objective and decide that you can't do it or aren't sure that you can. What do you do? Your next step is to look at the Learning Activities. Begin with Learning Activity #1. Read it. (Pause) Here it tells you to get Student Handout #1 called "Characteristics of the VOM" and read it. It also tells you to answer the Study Questions at the end of the Handout. Right now get Student Handout #1 from the Unit Packet and look through it. (Pause) Notice the Study Questions on the VOM. These will hlep you get ready for the questions on [illegible]. The Handout will give you the information you need to answer the questions. You should read it and practice answering the questions until you can answer them without references or assistance. After you work through Learning Activity #1 go on to Learning Activity #2. Read it now and then look at Student Handout #2 in your Unit Packet. (Pause) You can see that the Handout gives you information about how to use the Micronta

Multitester as an Ohmmeter. It also has a set of Study Questions. When the time comes to do it, read through the Handout and answer the Study Questions. Look at Learning Activity #3 and get Experiment #1 from the Unit Packet. (Pause) This gives you directions for using the VOM to measure resistance. When the time comes you should do this. Now look at Learning Activity #4. (Pause) After you have worked through Learning Activity Numbers 1, 2, and 3, you should ask the instructor to give the exam to you. Let's summarize: In order to learn how to do the Performance Objective, work through all the Learning Activities beginning with #1. Practice answering the Study Questions; do the experiment. After you have done all this, take the exam.

(Pause)

1. Begin with Learning Activity #1.
2. Read through the Study Questions.
3. Work through the Learning Activity.
4. Concentrate on those parts of the Learning Activity that are new to you or that you feel unsure of.
5. Redo the Study Questions until you can answer them correctly without references.
6. When you can do this, move on to the next Learning Activity and do the same thing.
7. When you have done this, work through the experiment until

YOU CAN TAKE RESISTANCE MEASUREMENTS WITHIN 20% OF THE ACTUAL VALUE.

8. ASK THE INSTRUCTOR FOR ASSISTANCE WHENEVER YOU GET STUCK OR HAVE A QUESTION ABOUT WHAT TO DO.
9. TAKE THE EXAM WHEN YOU FEEL READY.

YOU SHOULD DO THE LEARNING ACTIVITIES IN THE FOLLOWING WAY:

THE INSTRUCTOR IS HERE TO HELP YOU WHENEVER YOU HAVE QUESTIONS OR PROBLEMS. THE INSTRUCTOR WILL GIVE YOU THE EQUIPMENT YOU NEED TO DO THE LEARNING ACTIVITIES. YOU CAN CHECK YOUR ANSWERS TO THE STUDY QUESTIONS BY ASKING THE INSTRUCTOR FOR THE ANSWER SHEET.

(PAUSE)

WHAT HAPPENS WHEN YOU TAKE THE EXAMINATION AND DON'T PASS IT?

(PAUSE)

THIS IS A QUESTION YOU PROBABLY WANT TO ASK. WHEN YOU TAKE THE EXAM, THE INSTRUCTOR WILL CHECK YOUR WORK. THIS MEANS YOU WILL KNOW IF YOU DID IT CORRECTLY WITHIN THE CONDITIONS AND UP TO THE STANDARDS WHICH ARE WRITTEN IN THE PERFORMANCE OBJECTIVE. WHAT HAPPENS IF THE INSTRUCTOR SAYS YOU DIDN'T

MAKE IT? THIS IS LARGELY UP TO THE INSTRUCTOR BUT YOU WILL PROBABLY NEED TO REDO THOSE PARTS OF THE LEARNING ACTIVITIES THAT YOU NEED PRACTICE ON. THE IMPORTANT THING IS THAT YOU LEARN HOW TO DO THE PERFORMANCE OBJECTIVE. THE COURSE IS DESIGNED SO THAT YOU CAN DO THIS BY YOURSELF BY WORKING THROUGH THE LEARNING ACTIVITIES. THE INSTRUCTOR WILL HELP YOU WHEN YOU NEED IT, BUT TRY TO WORK ON YOUR OWN AS MUCH AS POSSIBLE. TAKING THE EXAM WILL TELL YOU HOW WELL YOU ARE DOING AND THE INSTRUCTOR WILL TELL YOU IF YOU NEED MORE PRACTICE. DON'T BE AFRAID TO TAKE THE EXAM. IT WILL TELL BOTH YOU AND THE INSTRUCTOR IF YOU NEED TO DO MORE WORK BEFORE GOING ON TO THE NEXT UNIT.

(PAUSE)

WHEN YOU GET A UNIT PACKET YOU SHOULD:

1. READ THE COMPETENCY STATEMENT AND THE PERFORMANCE OBJECTIVE.
2. ASK THE INSTRUCTOR TO TAKE THE EXAM IF YOU THINK YOU CAN DO IT RIGHT OFF.
3. IF YOU CAN'T DO IT RIGHT OFF, WORK THROUGH THE LEARNING ACTIVITIES.
4. TAKE THE EXAM AFTER YOU HAVE DONE THE LEARNING ACTIVITIES.
5. REDO ANY LEARNING ACTIVITY THE INSTRUCTOR TELLS YOU DO.
6. GO ON TO THE NEXT UNIT PACKET WHEN YOU SHOW YOU CAN DO THE PERFORMANCE OBJECTIVE.

7. ASK THE INSTRUCTOR FOR HELP WHENEVER YOU NEED IT.

YOU SHOULD FOLLOW THESE STEPS WHENEVER YOU GET A NEW UNIT PACKET. FOR THIS INTRODUCTION TO THE COURSE, WE ARE ASKING ALL OF YOU TO WORK THROUGH THE FIRST THREE UNITS OF THE COURSE, EVEN IF YOU ALREADY CAN DO ALL THE PERFORMANCE OBJECTIVES. THIS WILL GIVE YOU PRACTICE IN WORKING WITH THE COURSE MATERIALS AND THE COURSE FORMAT. THIS WILL MAKE IT EASIER FOR YOU AND THE INSTRUCTOR IN THE LONG RUN.

PART A

1. TWO 6-OHM RESISTORS CONNECTED IN SERIES WILL HAVE A TOTAL RESISTANCE OF:

   (A) 3 OHMS
   (B) 9 OHMS
   (C) 6 OHMS
   (D) 12 OHMS

2. TWO 10-OHM RESISTORS CONNECTED IN PARALLEL WILL HAVE A TOTAL RESISTANCE OF:

   (A) 5 OHMS
   (B) 20 OHMS
   (C) 15 OHMS
   (D) 25 OHMS

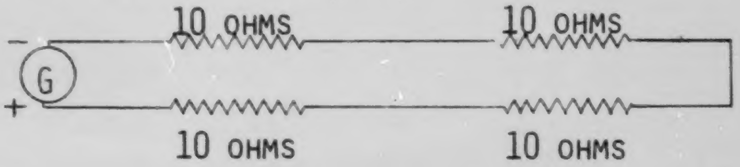
3. RESISTORS ARE USED IN CONVENTIONAL CONTROLLERS TO:

   (A) CHANGE AC TO DC
   (B) CHANGE DC TO AC
   (C) REDUCE STARTING CURRENT
   (D) PREVENT POWER LOSS

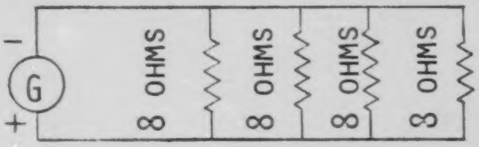
4. AS A RESISTOR HEATS, THE RESISTANCE VALUE:

   (A) REMAINS THE SAME
   (B) DECREASES
   (C) INCREASES
   (D) DOUBLES

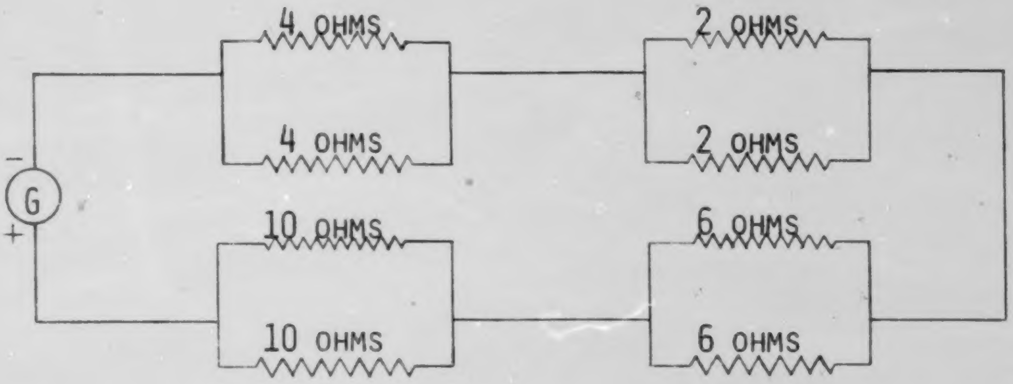
5. THE CIRCUIT SHOWN BELOW IS A ____________________ CIRCUIT HAVING A TOTAL RESISTANCE OF ____________________ OHMS.


10 OHMS
10 OHMS
G
-
+
10 OHMS
10 OHMS

6. THE CIRCUIT SHOWN BELOW IS A ____________________ CIRCUIT HAVING A TOTAL RESISTANCE OF ____________________ OHMS.

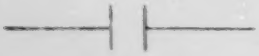
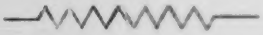
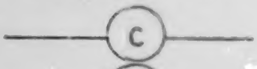
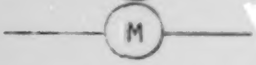
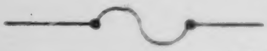
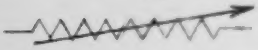
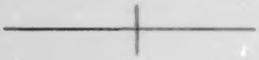
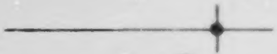
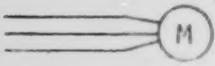
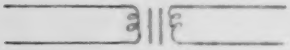

G
-
+
8 OHMS
8 OHMS
8 OHMS
8 OHMS

7. FIND THE TOTAL RESISTANCE FOR THE CIRCUIT SHOWN BELOW.


4 OHMS
4 OHMS
2 OHMS
2 OHMS
G
-
+
10 OHMS
10 OHMS
6 OHMS
6 OHMS

TOTAL RESISTANCE = ____________________

8. MATCH THE FOLLOWING SYMBOLS WITH THE PROPER LETTER.

A.		_____	1. DC MOTOR
B.		_____	2. OPERATING COIL
C.		_____	3. BATTERY
D.		_____	4. AC MOTOR
E.		_____	5. RESISTANCE
F.		_____	6. LINES CONNECTED
G.		_____	7. LINES NOT CONNECTED
H.		_____	8. SINGLE-PHASE TRANSFORMER
I.		_____	9. CONTACTOR
J.		_____	10. VARIABLE RESISTOR
			11. DC GENERATOR
			12. FUSE

9. A CONTACTOR IS OPERATED BY A:

(A) COIL
(B) SPRING
(C) WEIGHT
(D) RESISTOR

10. WHEN POWER IS APPLIED TO A COIL:

(A) A PERMANENT MAGNET IS FORMED
(B) DC POWER IS GENERATED
(C) AN ELECTROMAGNET IS FORMED
(D) AC POWER IS GENERATED

PART B

11. AC CURRENT IS:

(A) HIGH-VOLTAGE POWER PRODUCED BY BATTERIES CONNECTED IN SERIES

(B) CURRENT THAT TRAVELS AT A HIGH RATE OF SPEED AND THAT IS PRODUCED BY A RECTIFIER

(C) CURRENT THAT IS CONSTANTLY CHANGING IN MAGNITUDE AND PERIODICALLY CHANGING IN DIRECTION

(D) CURRENT USED ONLY FOR HOUSEHOLD UTILIZATION

12. DC POWER:

(A) IS CURRENT THAT CHANGES DIRECTION 60 TIMES A SECOND

(B) IS USED ONLY ON MOTORS OF LOW HORSEPOWER

(C) FLOWS IN ONE DIRECTION ONLY

(D) CAN BE CHANGED FROM LOW VOLTAGE TO HIGH VOLTAGE BY USE OF A TRANSFORMER

13. A DC MOTOR THAT WILL RUN TOO FAST IF THE LOAD IS REMOVED IS A:

(A) SHUNT MOTOR

(B) COMPOUND MOTOR

(C) SERIES MOTOR

(D) WOUND MOTOR

14. A RECTIFIER IS USED TO:

(A) STEP UP AC VOLTAGE
(B) STEP DOWN AC VOLTAGE
(C) CHANGE AC TO DC
(D) PROVIDE A GOOD GROUND FOR THREE-PHASE POWER

15. AN OVERLOAD IN AN ELECTRICAL CIRCUIT SERVES THE SAME PURPOSE AS A:

(A) CONTACTOR
(B) RESISTOR
(C) CONDUCTOR
(D) FUSE

16. WHEN CONNECTING A MOTOR TO A CONTROLLER IN THE MINES THE MOTOR SHOULD BE PROTECTED BY A:

(A) AUTOMATIC CIRCUIT BREAKER OF PROPER SIZE
(B) FUSED GROUNDED SYSTEM
(C) WIRE SIZE THAT WOULD SEPARATE IF OVERLOAD OCCURRED
(D) WARNING LIGHT IF POWER WERE REVERSED

17. WHEN USING A VOLTMETER TO CHECK AN UNKNOWN VOLTAGE, YOU SHOULD:

(A) SET METER ON MIDDLE RANGE
(B) SET METER ON HIGHEST RANGE
(C) BE CONCERNED ONLY THAT METER IS SET FOR AC OR DC
(D) CHECK WITH OHMMETER FIRST TO MAKE SURE THERE IS A COMPLETE CIRCUIT BEFORE TAKING A VOLTAGE READING

18. WHEN CONNECTING THREE-PHASE AC MOTORS TO CONTROLLERS AND THE MOTOR RUNS IN REVERSE, THE CONDITION CAN BE CORRECTED BY:

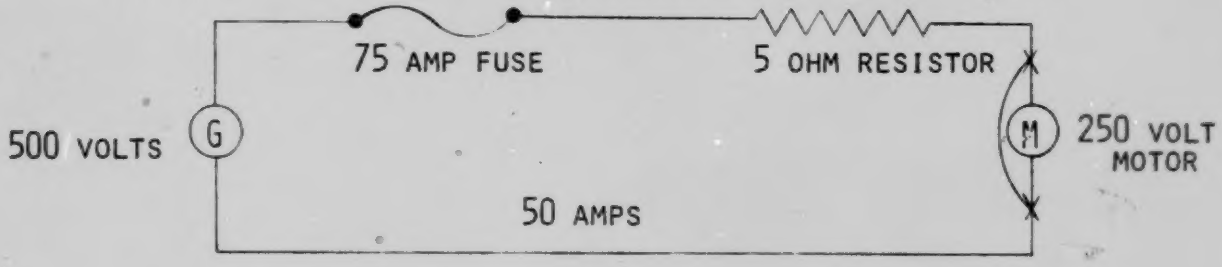
(A) REVERSING ANY TWO MOTOR LEADS
(B) CHANGING OVERLOAD SETTINGS
(C) TURNING POWER OFF AND ON QUICKLY
(D) INSTALLING A SMALLER FUSE

19. A MOTOR BEING SUPPLIED WITH A CABLE THAT IS TOO SMALL WILL:

(A) OVERHEAT MOTOR AND CABLE
(B) CAUSE THE MOTOR TO REVERSE
(C) CAUSE THE MOTOR TO RUN AWAY
(D) WILL NOT CAUSE ANY HARMFUL EFFECT

20. IN THE DIAGRAM SHOWN BELOW, THERE IS A SHORT CIRCUIT AT THE MOTOR TERMINALS. IN THIS CASE, THE:

(A) FUSE WOULD BLOW
(B) FUSE WOULD NOT BLOW
(C) MOTOR WOULD RUN IN REVERSE
(D) MOTOR WOULD BE SUPPLIED WITH FULL GENERATOR VOLTAGE



21. IN THE DIAGRAM SHOWN ABOVE, 50 AMPS ARE RETURNING TO THE GENERATOR. THIS MEANS THAT THE GENERATOR OUTPUT IS:

(A) 75 AMPS
(B) 50 AMPS
(C) 100 AMPS
(D) 125 AMPS

PART C

22. AN AC SQUIRREL CAGE INDUCTION MOTOR HAS:

(A) TWO SETS OF BRUSHES

(B) ONLY ONE SET OF BRUSHES

(C) SLIP RINGS

(D) A ROTAR

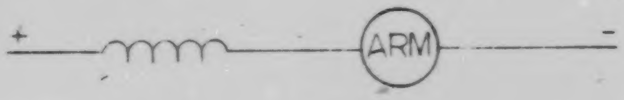
23. THE DIAGRAM SHOWN BELOW IS THAT OF:

(A) A SERIES-WOUND DC MOTOR

(B) A SHUNT-WOUND DC MOTOR

(C) A COMPOUND-WOUND DC MOTOR

(D) AN INDUCTION MOTOR



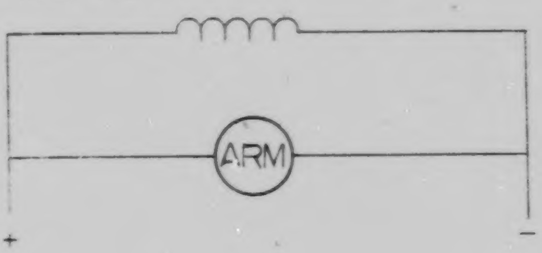
24. THE DIAGRAM BELOW SHOWS:

(A) A SERIES-WOUND DC MOTOR

(B) A SHUNT-WOUND DC MOTOR

(C) A COMPOUND-WOUND DC MOTOR

(D) AN INDUCTION MOTOR



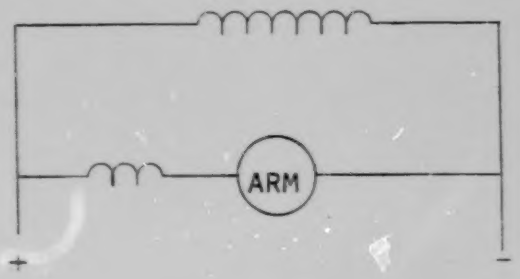
25. IN THE DIAGRAM SHOWN BELOW, THERE IS:

(A) A SERIES-WOUND DC MOTOR

(B) A SHUNT-WOUND DC MOTOR

(C) A COMPOUND-WOUND DC MOTOR

(D) AN INDUCTION MOTOR



26. AC-POWERED MINE EQUIPMENT USED AT THE FACE, WHICH RECEIVES ITS POWER THROUGH A TRAILING CABLE:

(A) HAS THREE POWER CONDUCTORS IN CABLE

(B) HAS TWO POWER CONDUCTORS IN CABLE

(C) HAS SIX POWER CONDUCTORS IN CABLE

(D) NEEDS NO GROUND CONDUCTORS IN CABLE

27. MOST VOLTAGE CONTROLLERS HAVE:

(A) DIODES TO REDUCE VOLTAGE

(B) RESISTORS TO REDUCE VOLTAGE

(C) OIL SWITCHES TO REDUCE VOLTAGE

(D) CIRCUIT BREAKERS TO REDUCE VOLTAGE

28. OVERLOADS ARE PROVIDED IN CIRCUITS TO PREVENT:

(A) EXCESSIVE VOLTAGE
(B) EXCESSIVE CURRENT
(C) REVERSE FLOW
(D) GROUND FAULT

29. A CONTACTOR THAT DOES NOT HAVE AMPLE CURRENT-CARRYING CAPACITY WILL:

(A) HAVE EXCESSIVE BURNING OF THE TIPS
(B) NOT OPERATE AT ALL
(C) CAUSE THE CURRENT TO REVERSE
(D) CAUSE THE TRAILING CABLE TO HEAT

30. CONTROL CIRCUITS ARE PROTECTED BY:

(A) FUSES
(B) MERCURY TUBES
(C) TRANSFORMERS
(D) RESISTORS

31. ON AC CONTROLLERS THE CONTROL CIRCUIT HAS A LOWER VOLTAGE THAN THE POWER CIRCUIT; THIS LOWER VOLTAGE IS USUALLY OBTAINED BY THE USE OF:

(A) A STEP-DOWN TRANSFORMER
(B) AN INDEPENDENT SOURCE
(C) A SMALLER WIRE
(D) DC VOLTAGE

PART D

32. A CABLE OR CIRCUIT THAT IS OVERLOADED WILL SHOW SIGNS OF:

(A) HEATING
(B) BECOMING COLD AND BRITTLE
(C) WIRES BREAKING LOOSE AT CONNECTIONS
(D) NOTHING ABNORMAL

33. THE POWER CIRCUIT IS USUALLY SHOWN ON A SCHEMATIC DRAWING BY:

(A) BROKEN LINES
(B) HEAVY LINES
(C) LIGHT LINES
(D) LINES WITH ARROWS TO SHOW DIRECTION OF FLOW

34. A TRANSFORMER IS USED TO:

(A) CHANGE AC TO DC
(B) CHARGE BATTERIES
(C) STEP UP OR STEP DOWN DC POWER
(D) STEP UP OR STEP DOWN AC POWER

35. THE MOST COMMON AC POWER USED AROUND THE MINES IS:

(A) SINGLE PHASE
(B) THREE PHASE
(C) PULSATING AC
(D) USED FOR TRACK HAULAGE

36. NAME FOUR HOOKUPS FOR THREE-PHASE TRANSFORMERS.

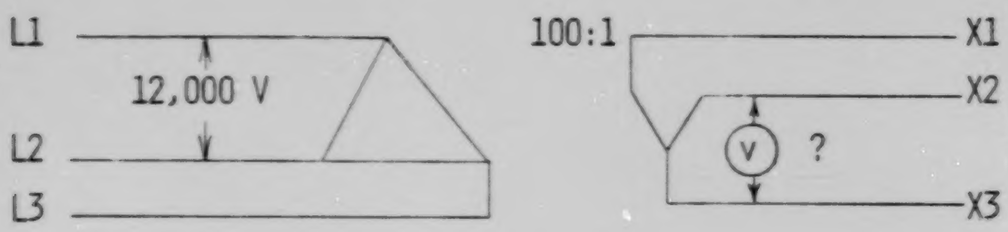
A. ____________________

B. ____________________

C. ____________________

D. ____________________

37. BELOW IS A SCHEMATIC DRAWING OF THREE SINGLE-PHASE TRANSFORMERS HOOKED UP TO PROVIDE THREE-PHASE POWER.



VOLTAGE ACROSS X2 TO X3 ON THE SECONDARY SIDE IS ____________.

38. THE SECONDARY VOLTAGE OF A TRANSFORMER IS DETERMINED BY:

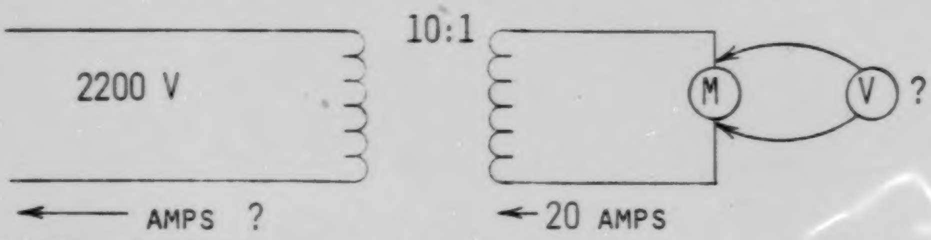
(A) TURNS RATIO

(B) SIZE OF TRANSFORMER

(C) TYPE OF COOLING FLUID USED

(D) LOAD ON SECONDARY

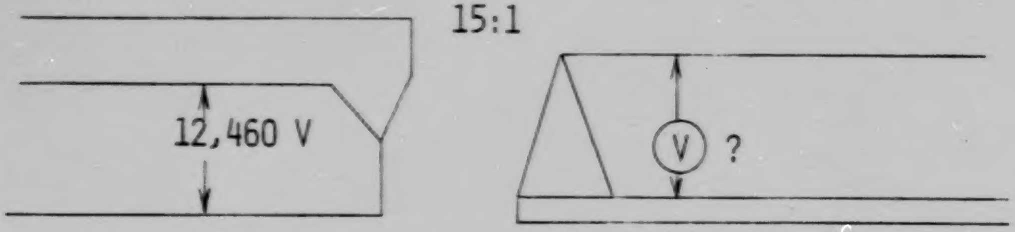
39. IN THE DIAGRAM SHOWN BELOW, FIND THE VOLTAGE AT THE MOTOR AND THE AMPERAGE ON THE PRIMARY SIDE OF THE TRANSFORMER.



VOLTAGE AT MOTOR ____________________

AMPERAGE ON PRIMARY ____________________

40. IN THE DIAGRAM SHOWN BELOW, FIND THE VOLTAGE ON SECONDARY AND TELL WHAT KIND OF A HOOKUP IT IS.



VOLTAGE ON SECONDARY ________________________________

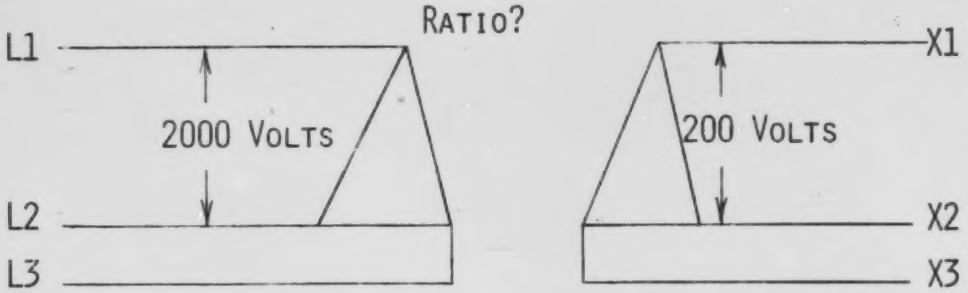
KIND OF HOOKUP ______________________________________

PART E

41. ZIGZAG TRANSFORMERS ARE USED TO:

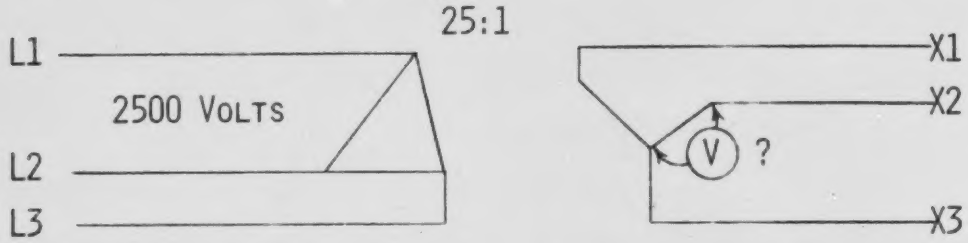
(A) PROVIDE A DERIVED NEUTRAL POINT FOR USE AS A GROUNDING POINT ON A DELTA SECONDARY
(B) STEP DOWN SECONDARY VOLTAGE
(C) LIMIT CURRENT OVERLOAD
(D) CONVERT AC TO DC

42. IN THE DIAGRAM SHOWN BELOW, WHAT IS THE TURNS RATIO OF THE TRANSFORMER?


RATIO?
L1
L2
L3
2000 VOLTS
X1
X2
X3
200 VOLTS

_____________________ RATIO

43. FIND THE PHASE VOLTAGE ON SECONDARY SHOWN IN THE DIAGRAM BELOW.


25:1
L1
L2
L3
2500 VOLTS
X1
X2
X3
V
?

_________________________ VOLTS

44. NAME THREE TYPES OF THREE-PHASE MOTORS USED AROUND THE COAL MINES:

A.

B.

C.

45. DC VOLTAGE IS NOT USED TO FEED RECTIFIERS.

(A) TRUE

(B) FALSE

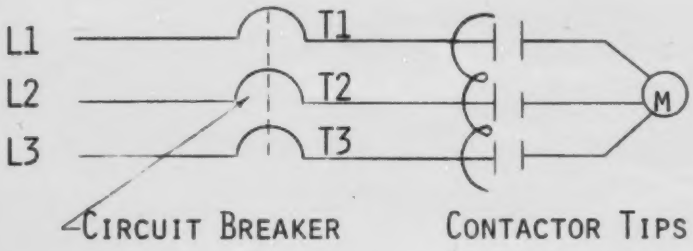
46. SHOWN BELOW IS A POWER CIRCUIT OF A THREE-PHASE MOTOR CONTROL. IF CONTACTS ON L2 WOULD NOT MAKE CONTACT:

(A) MOTOR WOULD NOT RUN

(B) MOTOR WOULD RUN

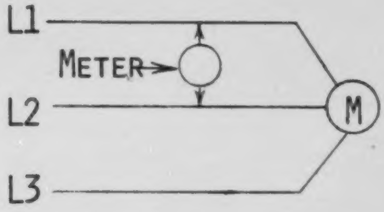
(C) MOTOR WOULD RUN BUT IN REVERSE

(D) IT WOULD NOT HAVE ANY EFFECT


L1
L2
L3
T1
T2
T3
M
CIRCUIT BREAKER
CONTACTOR TIPS

47. IN THE DIAGRAM BELOW WITH THE METER CONNECTED AS SHOWN, ONE WOULD BE CHECKING FOR:

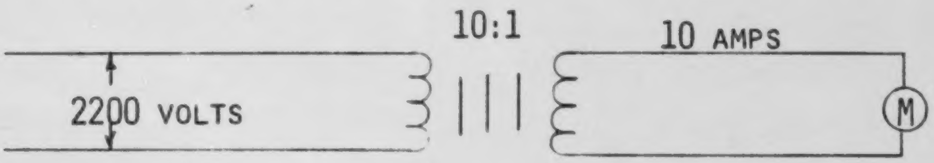
(A) VOLTAGE
(B) RESISTANCE
(C) AMPERAGE
(D) WATTAGE



48. A MOTOR CONNECTED TO 120 VOLTS DRAWS 20 AMPS. THE NUMBER OF WATTS OF POWER USED IS:

(A) 6 WATTS
(B) 12 WATTS
(C) 2,400 WATTS
(D) 5,000 WATTS

49. BELOW IS A DIAGRAM OF A MOTOR HOOKED TO A TRANSFORMER. FIND THE VOLTAGE ON SECONDARY, AMPERAGE ON PRIMARY, WATTS OF POWER USED BY MOTOR, AND HORSEPOWER OF MOTOR. CONSIDER MOTOR AND TRANSFORMER AS 100 PERCENT EFFICIENT.



VOLTAGE ON SECONDARY __________ WATTS USED BY MOTOR ______

AMPERAGE ON PRIMARY __________ HORSEPOWER OF MOTOR ______

50. To measure voltage, a voltmeter should be connected:

(A) PARALLEL WITH LOAD
(B) SERIES WITH LOAD
(C) EITHER PARALLEL OR SERIES
(D) TO AC POWER ONLY

51. An ammeter should always be connected:

(A) IN PARALLEL WITH LOAD
(B) IN SERIES WITH LOAD
(C) EITHER IN PARALLEL OR IN SERIES WITH LOAD
(D) TO DC POWER ONLY

PART F

PLACE A "P" IN THE BLANK IF THE STATEMENT APPLIES TO A PARALLEL CIRCUIT. PLACE AN "S" IN THE BLANK IF THE STATEMENT APPLIES TO A SERIES CIRCUIT.

52. ____ A CIRCUIT WHICH HAS ONLY ONE PATH FOR CURRENT TO FLOW.

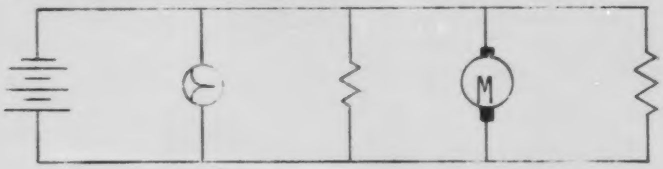
53. ____ A CIRCUIT WHICH HAS MORE THAN ONE PATH FOR CURRENT TO FLOW.

54. ____ THE VOLTAGE ACROSS EVERY COMPONENT IN THE CIRCUIT IS THE SAME.

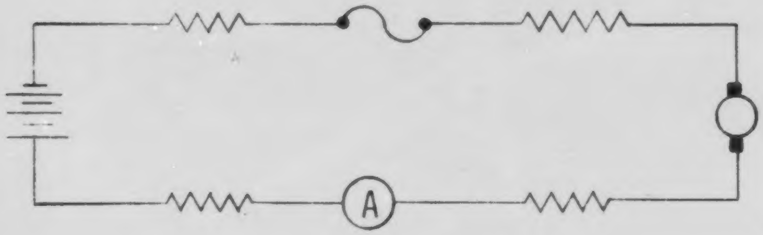
55. ____ THE CURRENT IS THE SAME THROUGHOUT THE CIRCUIT.

56. ____ THE CURRENT THROUGH EACH COMPONENT IN THE CIRCUIT MAY NOT BE THE SAME.

57. ____ THIS CICRUIT.



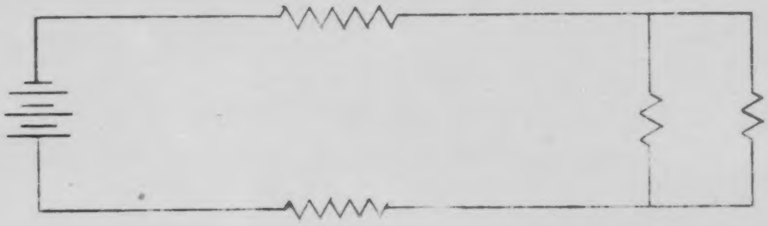
58. ____ THIS CIRCUIT.



59. ____ A VOLTMETER CORRECTLY CONNECTED SO AS TO MEASURE THE VOLTAGE APPLIED TO A CIRCUIT COMPONENT.

60. ____ AN AMMETER CORRECTLY CONNECTED SO AS TO MEASURE THE AMOUNT OF CURRENT PASSING THROUGH A CIRCUIT COMPONENT.

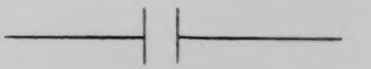
61. ____ THIS CIRCUIT.

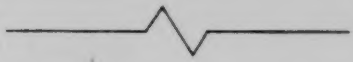


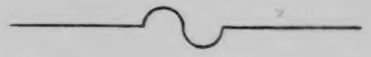
PART G

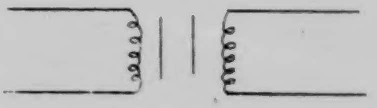
MATCH THE FOLLOWING ELECTRICAL COMPONENTS AND DEVICES WITH THE SYMBOL USED TO REPRESENT THEM. USE EACH SYMBOL ONLY ONCE.

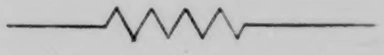
62. ____ A DELTA CONNECTION
63. ____ NORMALLY OPEN CONTACT
64. ____ OVERLOAD COIL
65. ____ TRANSFORMER
66. ____ FUSE
67. ____ RESISTOR
68. ____ THREE PHASE MOTOR
69. ____ MOTOR ARMATURE
70. ____ RECTIFIER DIODE (GROUNDING)
71. ____ CIRCUIT BREAKER
72. ____ BATTERY
73. ____ VOLTMETER
74. ____ WYE OR STAR CONNECTION

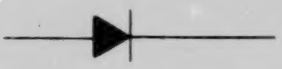
A.


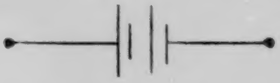
B.


C.


D.


E.


F.


G.


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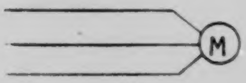

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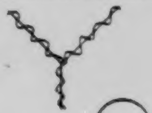
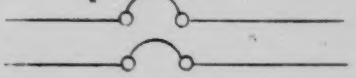
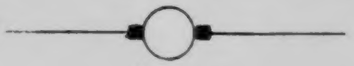
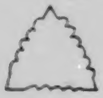
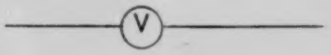


J.


K.


L.


M.


MATCH THE FOLLOWING ELECTRICAL COMPONENTS AND DEVICES WITH THE SYMBOL USED TO REPRESENT THEM. USE EACH SYMBOL ONLY ONCE.

75. ____ NORMALLY CLOSED CONTACT

76. ____ OPERATING COIL

77. ____ MERCURY TUBE (NORMALLY OPEN TIME DELAY CLOSING)

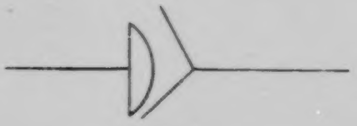
78. ____ MERCURY TUBE (NORMALLY CLOSED INSTANTANEOUSLY OPENING AND CLOSING)

79. ____ NORMALLY OPEN PUSH BUTTON SWITCH

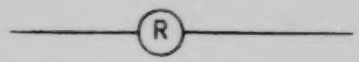
80. ____ NORMALLY CLOSED PUSH BUTTON SWITCH

81. ____ MERCURY TUBE (NORMALLY OPEN, TIME DELAY OPENING AND CLOSING)

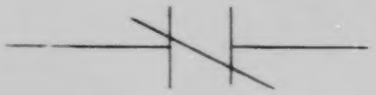
N.



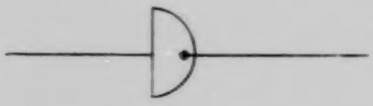
O.



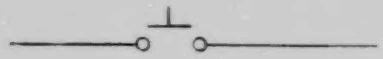
P.



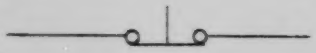
Q.



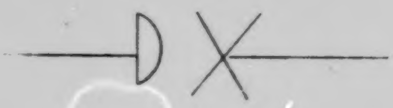
R.



S.



T.



PART H

INDICATE THE CORRECT ANSWER FOR EACH OF THE FOLLOWING BY PLACING THE CORRESPONDING LETTER (A, B, C, OR D) IN THE SPACE PROVIDED.

82. _____ A RECTIFIER IS USED TO

A. CHANGE DIRECT CURRENT TO ALTERNATING CURRENT.
B. CHANGE ALTERNATING CURRENT TO DIRECT CURRENT.
C. STEP UP ALTERNATING CURRENT VOLTAGES.
D. LIMIT MOTOR STARTING CURRENT.

83. _____ THREE 30-OHM RESISTORS CONNECTED IN PARALLEL WILL RESULT IN A TOTAL RESISTANCE OF

A. 10 OHMS
B. 3 OHMS
C. 90 OHMS
D. .3 OHM

84. _____ THREE 30-OHM RESISTORS CONNECTED IN SERIES WILL RESULT IN A TOTAL RESISTANCE OF

A. 10 OHMS
B. 3 OHMS
C. 90 OHMS
D. .3 OHM

85. _____ A TRANSFORMER IS USED TO

A. STEP UP DIRECT CURRENT VOLTAGES.
B. STEP DOWN DIRECT CURRENT VOLTAGES.
C. BOTH OF THE ABOVE.
D. NONE OF THE ABOVE.

86. _____ AN OPERATING COIL OF A CONTACTOR IS USED TO

A. OPEN ALL NORMALLY CLOSED CONTACTS CONNECTED TO IT.

B. CLOSE ALL NORMALLY OPEN CONTACTS CONNECTED TO IT.

C. BOTH OF THE ABOVE.

D. NONE OF THE ABOVE.

87. _____ INSTANTANEOUS OVERLOAD PROTECTION CAN BE PROVIDED FOR BY USING

A. THERMAL OVERLOAD DEVICES.

B. MAGNETIC COILS AND MERCURY SWITCHES.

C. CURRENT TRANSFORMERS.

D. NONE OF THE ABOVE.

88. _____ RESISTORS ARE USED TO

A. LIMIT CURRENT FLOW IN MOTOR CIRCUITS.

B. REDUCE LINE VOLTAGES FOR LIGHTING CIRCUITS ON MACHINES.

C. PROVIDE SPEED CONTROL OF DC MOTORS.

D. ALL OF THE ABOVE.

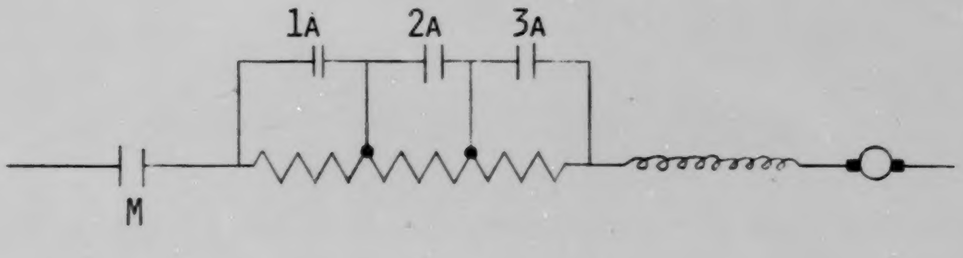
89. _____ HOW MANY SPEED STEPS ARE THERE IN THIS CONTROLLER?

A. 5

B. 4

C. 3

D. 2



90. _____ THE SECONDARY WINDING OF A TRANSFORMER IS

A. THE HIGH VOLTAGE WINDING

B. THE LOW VOLTAGE WINDING

C. THE WINDING TO WHICH POWER IS CONNECTED

D. THE LOAD SIDE OF THE TRANSFORMER

91. _____ OVERLOAD CONTACTS ARE ALWAYS CONNECTED IN SERIES WITH

A. START SWITCH

B. STOP SWITCH

C. OPERATING COIL

D. ALL OF THE ABOVE

PART I

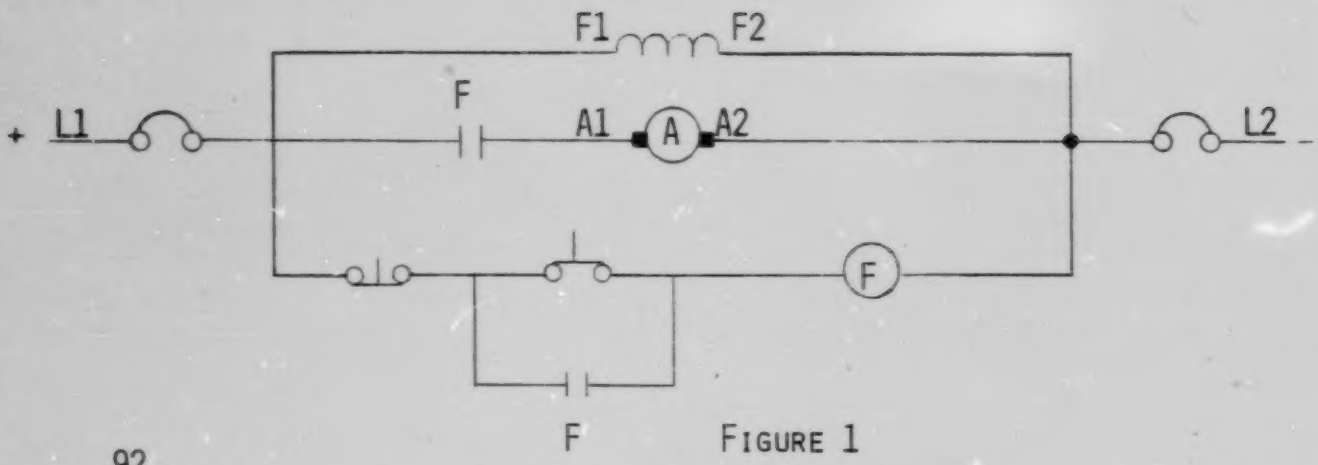


FIGURE 1

92. ____

THE MOTOR IN THE ABOVE DIAGRAM IS A

A. DIRECT CURRENT SERIES MOTOR.

B. DIRECT CURRENT COMPOUND MOTOR.

C. DIRECT CURRENT SHUNT MOTOR.

D. ALTERNATING CURRENT INDUCTION MOTOR.

93. ____

THERE ARE TWO "F" CONTACTS IN THE ABOVE CIRCUIT.

A. BOTH "F" CONTACTS ARE NORMALLY CLOSED.

B. ONE "F" CONTACT IS NORMALLY CLOSED AND ONE IS NORMALLY OPEN.

C. BOTH "F" CONTACTS ARE NORMALLY OPEN.

D. WHEN ONE "F" CONTACT OPENS, THE OTHER "F" CONTACT CLOSES.

94. ____

THE FIELD WINDING OF THE MOTOR IS CONNECTED TO THE POWER

A. ONLY WHEN THE START BUTTON IS DEPRESSED.

B. ONLY IF THE "F" COIL IS ENERGIZED.

C. AT ALL TIMES THE CIRCUIT BREAKER IS CLOSED.

D. ONLY WHEN THE ARMATURE IS CONNECTED TO THE POWER.

95. ____

ONE OF THE "F" CONTACTS CONNECTS THE ARMATURE TO THE POWER SOURCE. THE OTHER "F" CONTACT

A. PERMITS THE OPERATOR TO RELEASE THE START BUTTON ONCE IT HAS BEEN DEPRESSED.

B. MAINTAINS THE CONTROL CIRCUIT KEEPING THE "F" COIL ENERGIZED ONCE THE START BUTTON HAS BEEN DEPRESSED.

C. IS IN SERIES WITH THE STOP BUTTON AND "F" COIL WHEN THE MOTOR IS RUNNING.

D. ALL OF THE ABOVE.

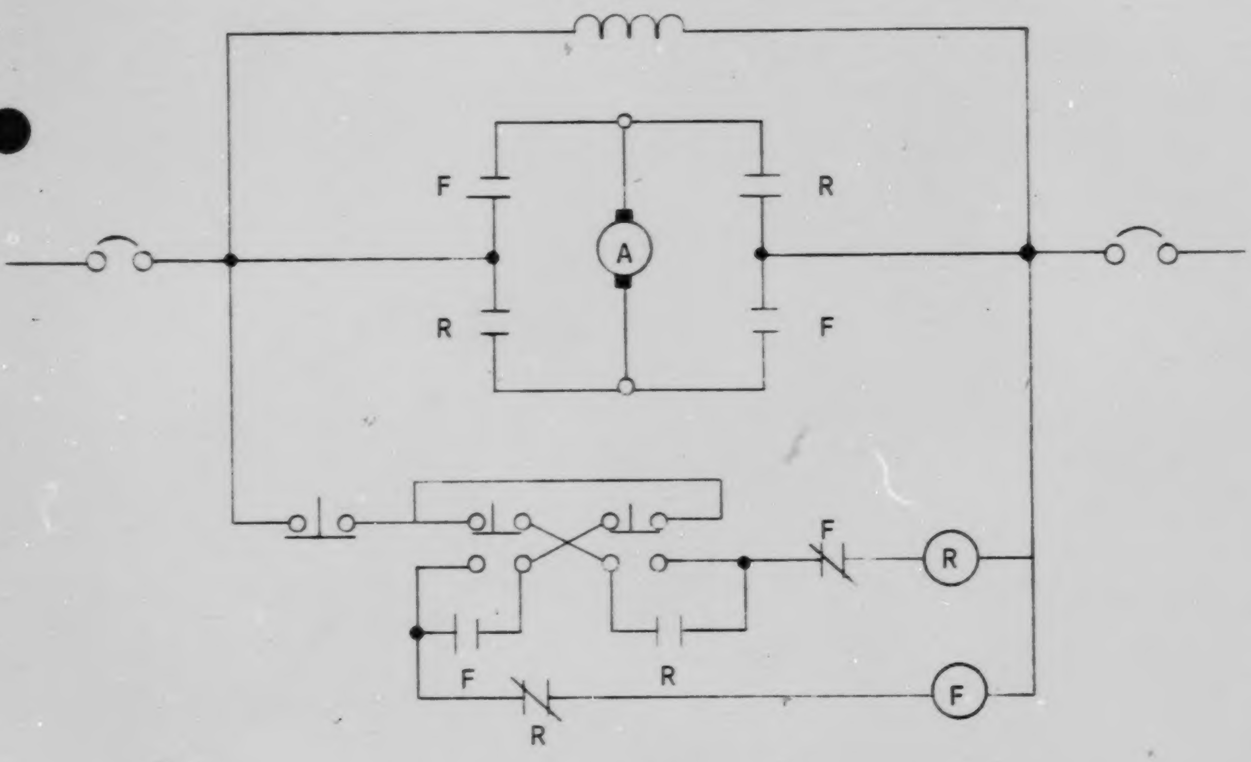


FIGURE 2

96. ____

IN FIGURE 2, DEPRESSING THE REVERSE BUTTON WILL ENERGIZE THE REVERSE "R" COIL WHICH

A. WILL CAUSE TWO "R" CONTACTS TO CLOSE AND TWO "R" CONTACTS TO OPEN.

B. WILL CAUSE ONE "R" CONTACT TO CLOSE AND THREE TO OPEN.

C. WILL START THE MOTOR IN THE CLOCKWISE DIRECTION.

D. WILL PREVENT THE "F" COIL FROM BEING ENERGIZED.

97. ____

AN ELECTRICAL INTERLOCK IS A METHOD OF PROTECTING A DEVICE OR EQUIPMENT FROM DAMAGE DUE TO IMPROPER OPERATION OR TO PROVIDE SAFETY TO INEXPERIENCED PERSONNEL. HOW MANY INTERLOCKS ARE PROVIDED IN FIGURE 2?

A. 4

B. 3

C. 2

D. 1

98. ____

THE ABOVE MOTOR CONTROLLER IS

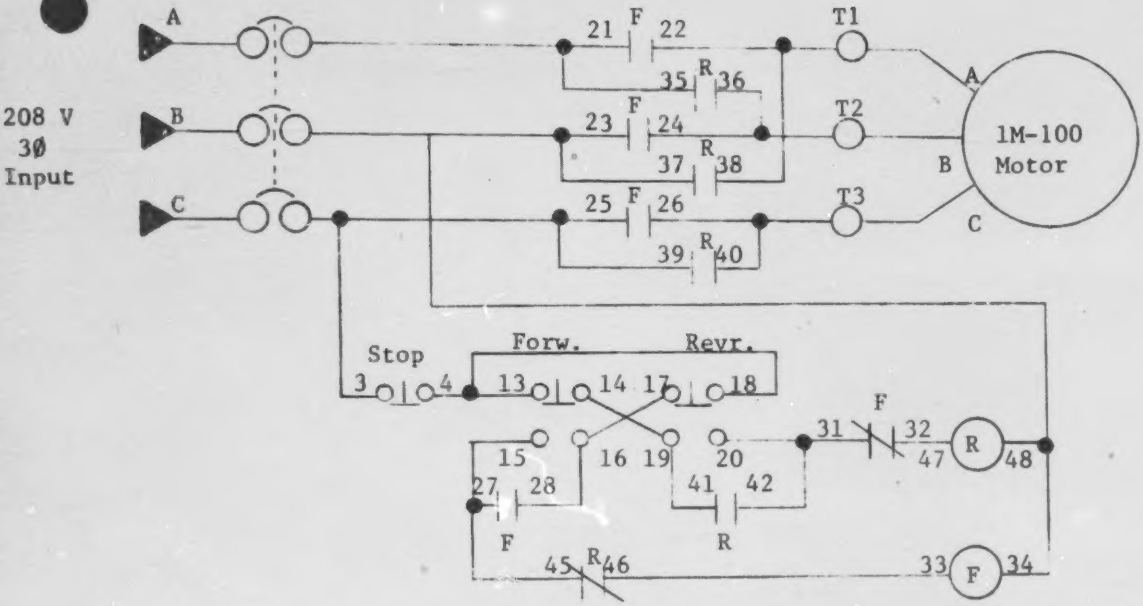
A. A FULL VOLTAGE REVERSING STARTER

B. AN ACROSS-THE-LINE REVERSING STARTER

C. BOTH OF THE ABOVE.

D. NONE OF THE ABOVE.

PART J



208 V
30
Input
A
B
C
21
F
22
35
R
36
23
F
24
37
R
38
25
F
26
39
R
40
T1
T2
T3
A
B
C
1M-100
Motor
Stop
3
4
Forw.
13
14
Revr.
17
18
15
16
19
20
27
28
F
41
42
R
F
31
32
47
R
48
45
R
46
33
F
34

FIGURE 4

THE MOTOR IN THE ABOVE DIAGRAM WILL RUN IN THE FORWARD DIRECTION, BUT NOT IN THE REVERSE DIRECTION. YOU SUSPECT THE TROUBLE TO BE IN THE CONTROL CIRCUIT. USING YOUR VOLTMETER, YOU BEGIN OBTAINING READINGS FROM POINT NO. 48 ON THE "R" COIL TO THE FOLLOWING POINTS: (LIST THE READING YOU SHOULD OBTAIN AT EACH POINT IF THE COMPONENT IS NORMAL)

99. FROM POINT 48 TO POINT 3 ____________

100. FROM POINT 48 TO POINT 4 ____________

101. FROM POINT 48 TO POINT 13 ____________

102. FROM POINT 48 TO POINT 14 ____________

103. FROM POINT 48 TO POINT 19 ____________

104. FROM POINT 48 TO POINT 20 ____________, WITH REVERSE BUTTON DEPRESSED ____________

105. FROM POINT 48 TO POINT 31 ________, WITH BUTTON DEPRESSED ________

106. FROM POINT 48 TO POINT 32 ________, WITH BUTTON DEPRESSED ________

107. IF ALL YOUR READINGS WERE NORMAL, WHY DOESN'T THE MOTOR RUN IN THE REVERSE DIRECTION?

108. WHICH OF THE ABOVE READINGS WERE UNNECESSARY?

109. YOU OBTAINED A READING AT POINT 31 WITH THE REVERSE BUTTON DEPRESSED, BUT DID NOT OBTAIN A READING AT POINT 32. WHAT WOULD BE YOUR TROUBLE?

PART K

COMPLETE THE SENTENCE CORRECTLY BY WRITING IN THE MISSING WORD ON THE ___BLANK___ PROVIDED.

110. INTERLOCKING CONTACTS ON AC LINE STARTERS ARE CLOSED ______________________.

111. INTERLOCKING CONTACTS ON AC LINE STARTERS COMPLETE A ____________ CIRCUIT.

112. MERCURY TUBES ARE OPENED AND/OR CLOSED DUE TO A ____________ ____________ PROVIDED BY AN OPERATING COIL.

113. ARCING AT DC CONTACTORS IS MINIMIZED OR REDUCED DUE TO THE FUNCTION OF A ________________ COIL.

114. AN OPERATING COIL FOR EITHER AN AC OR DC CONTACTOR IS USED PRIMARILY TO ______________ THE CONTACTS.

115. CIRCUIT PROTECTION PROVIDED BY THERMAL RELAYS ARE OPERATED WHEN THE ____________ ________________ BECOME TOO HOT.

PART L

REFER TO THE TWO DIAGRAMS PROVIDED TO ANSWER ALL QUESTIONS (DIAGRAMS "A" AND "B"). USE THE ANSWER SHEET PROVIDED TO ANSWER THE QUESTIONS.

QUESTIONS 116 THROUGH 119 REFER TO DIAGRAM A.

116. WHICH MOTOR CIRCUIT IS PROVIDED WITH REVERSING CONTACTORS?

117. WHICH OF THE TWO MAIN MOTORS WOULD START FIRST? WHY?

118. IN THE PUMP AND MAIN CONTROL CIRCUIT, WHICH CONTACTS MAINTAIN THE CIRCUIT WHEN THE CONTROL SWITCH IS IN THE RUN POSITION? WHAT DO WE CALL THESE CONTACTS?

119. IN THE MAIN MOTOR CIRCUIT, THE LEFT MAIN MOTOR STOPS DUE TO AN OVERLOAD, LM3 OPENING; HOW WILL THIS AFFECT THE RIGHT MAIN MOTOR, IF AT ALL?

QUESTIONS 120 THROUGH 124 REFER TO DIAGRAM B

120. IN THE OPERATING CIRCUIT OF THE HEAD AND TRACTION MOTORS, WHAT IS THE PURPOSE OF M1 MERCURY TUBE?

121. EXPLAIN WHAT HAPPENS TO THE TRACTION MOTORS WHEN CONTACTOR MA CLOSES.

122. WHICH CONTACTOR IN THE CONVEYOR POWER CIRCUIT PROVIDES THE SAME FUNCTION AS MA CONTACTOR IN THE HEAD AND TRACTION CIRCUIT?

123. WHICH OPERATING COIL IN THE HEAD AND TRACTION CIRCUIT CLOSES A "TIME DELAY CLOSING" MERCURY TUBE?

124. IF THE SERIES STARTING RESISTOR IN THE HEAD AND TRACTION CIRCUIT WERE OPEN CIRCUITED, WOULD THE HEAD AND TRACTION MOTORS START? EXPLAIN.

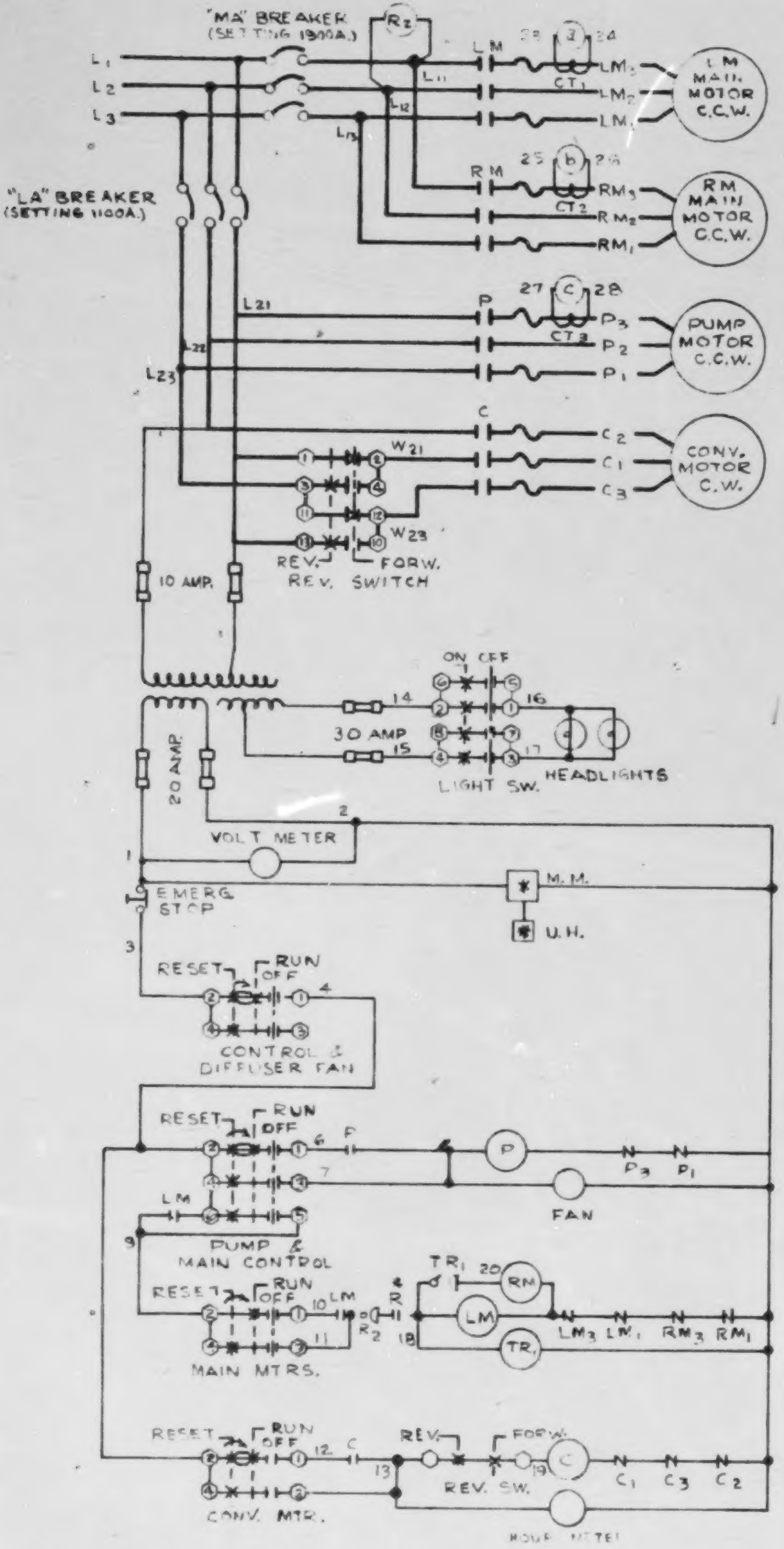

"MA" BREAKER
(SETTING 1300A.)
R2
L1
L2
L3
L11
L12
L13
LM
23
a
24
CT1
LM3
LM2
LM1
LM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A.)
RM
25
b
26
CT2
RM3
RM2
RM1
RM MAIN MOTOR C.C.W.
L21
L22
L23
P
27
c
28
CT3
P3
P2
P1
PUMP MOTOR C.C.W.
C
W21
C2
C1
C3
CONV. MOTOR C.W.
W23
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
30 AMP.
15
17
HEADLIGHTS
LIGHT SW.
20 AMP.
2
VOLT METER
1
M.M.
EMERG. STOP
U.H.
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
6
7
P
FAN
P3
P1
LM
9
PUMP & MAIN CONTROL
TR1
20
RM
LM
10
R2
R
18
TR1
LM3
LM1
RM3
RM1
11
MAIN MTRS.
12
C
13
REV.
FORW.
19
C
REV. SW.
C1
C3
C2
CONV. MTR.
HOUR METER

DIAGRAM "A"
P-33

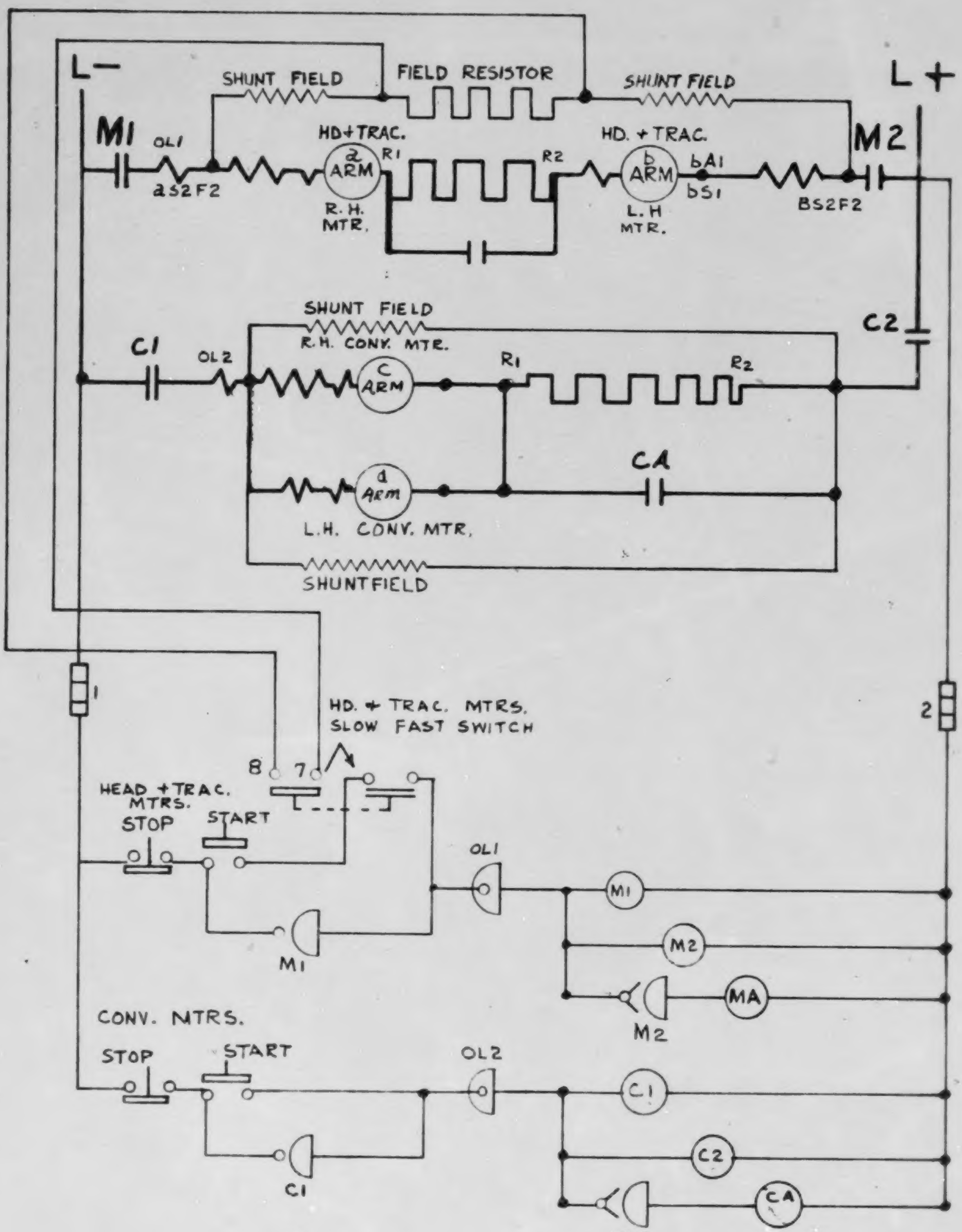

L−
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
HD+TRAC.
R1
R2
HD. + TRAC.
M2
a
ARM
b
ARM
bA1
bS1
aS2F2
BS2F2
R. H.
MTR.
L. H
MTR.
SHUNT FIELD
R.H. CONV. MTR.
C2
C1
OL2
c
ARM
R1
R2
CA
d
Arm
L.H. CONV. MTR.
SHUNTFIELD
1
2
HD. + TRAC. MTRS.
SLOW FAST SWITCH
8
7
HEAD + TRAC.
MTRS.
STOP
START
OL1
M1
M1
M2
M2
MA
CONV. MTRS.
STOP
START
OL2
C1
C1
C2
C2
CA

DIAGRAM "B"

P-34

PART M

INSTRUCTIONS TO STUDENT:

1. READ ALL THE INSTRUCTIONS BEFORE PROCEEDING WITH THE EXAMINATION.

2. GO TO THE DISPLAY TABLE TO THE REAR OF THE CLASSROOM AND IDENTIFY EACH COMPONENT THAT YOU FIND THERE.

3. WRITE THE NAME OF EACH COMPONENT ON YOUR ANSWER SHEET IN THE SPACE PROVIDED; E.G., IF PART #1 IS A DC CONTACTOR, YOUR ANSWER SHEET WOULD APPEAR AS FOLLOWS:

NAME OF PARK	PART SYMBOL
#1. DC CONTACTOR	(DRAW IN ITS SYMBOL)

4. CONDITIONS:
   - (A) ONLY ONE STUDENT AT THE DISPLAY AT ANY TIME.
   - (B) WRITE IN THE NAMES AND RETURN TO YOUR SEAT.
   - (C) DRAW IN THE SYMBOL REPRESENTING THE PART AFTER YOU RETURN TO YOUR SEAT.
   - (D) ALL NAMES OF PARTS MUST BE CORRECT AND AGREE WITH THE SYMBOL REPRESENTING IT.

5. IF YOU UNDERSTAND ALL THE INSTRUCTIONS, INFORM THE INSTRUCTOR YOU ARE READY AND PROCEED.

PART N

CONDITIONS FOR EXAMINATION, PART I, IDENTIFICATION.

A STUDENT WILL BE REQUIRED TO GO TO A DISPLAY TABLE ON WHICH WILL BE SEVERAL CONVENTIONAL ELECTRICAL COMPONENTS (SEE ENCLOSED LIST). HE WILL BE REQUIRED TO WRITE THE PROPER IDENTITY OF EACH PIECE AND RETURN TO HIS SEAT TO COMPLETE THE REMAINDER OF THE EXAMINATION. EACH PIECE WILL HAVE AN IDENTIFYING NUMBER ASSIGNED TO IT AND THE STUDENT WILL BE REQUIRED TO WRITE IN THE PROPER NAME OF THE PART CORRESPONDING TO ITS NUMBER ON THE ANSWER SHEET AND DRAW IN ITS SYMBOL OPPOSITE ITS NAME.

SEE STUDENT INSTRUCTIONS.

STUDENT COMPETENCY SHEET #1

UNIT 01: METERS, PART I

COMPETENCY STATEMENT: IDENTIFIES THE GENERAL CHARACTERISTICS OF THE MULTIMETER (VOM) AND USES THE MULTIMETER (VOM) AS AN OHMMETER TO CHECK RESISTANCE.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL USE THE MULTIMETER TO MEASURE RESISTANCE AND ANSWER QUESTIONS ABOUT ITS USE.

CONDITIONS: YOU HAVE 10 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARDS: ALL YOUR ANSWERS MUST BE CORRECT. ALL READINGS MUST BE WITHIN 20% OF THE ACTUAL RESISTANCE VALUE.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "CHARACTERISTICS OF THE VOM," AND THE MICRONTA MULTITESTER USED IN THIS PROGRAM. READ THE HANDOUT WHILE USING THE MULTITESTER AS A REFERENCE. ANSWER THE STUDY QUESTIONS AT THE END OF THE HANDOUT.
2. GET STUDENT HANDOUT #2, "THE OHMMETER," AND THE MICRONTA MULTITESTER USED IN THIS PROGRAM. READ THE HANDOUT WHILE USING THE MULTITESTER AS A REFERENCE. ANSWER THE STUDY

QUESTIONS AT THE END OF THE HANDOUT.

3. GET EXPERIMENT #1 "THE OHMMETER." DO ALL OF THE STEPS IN THE EXPERIMENT.

4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

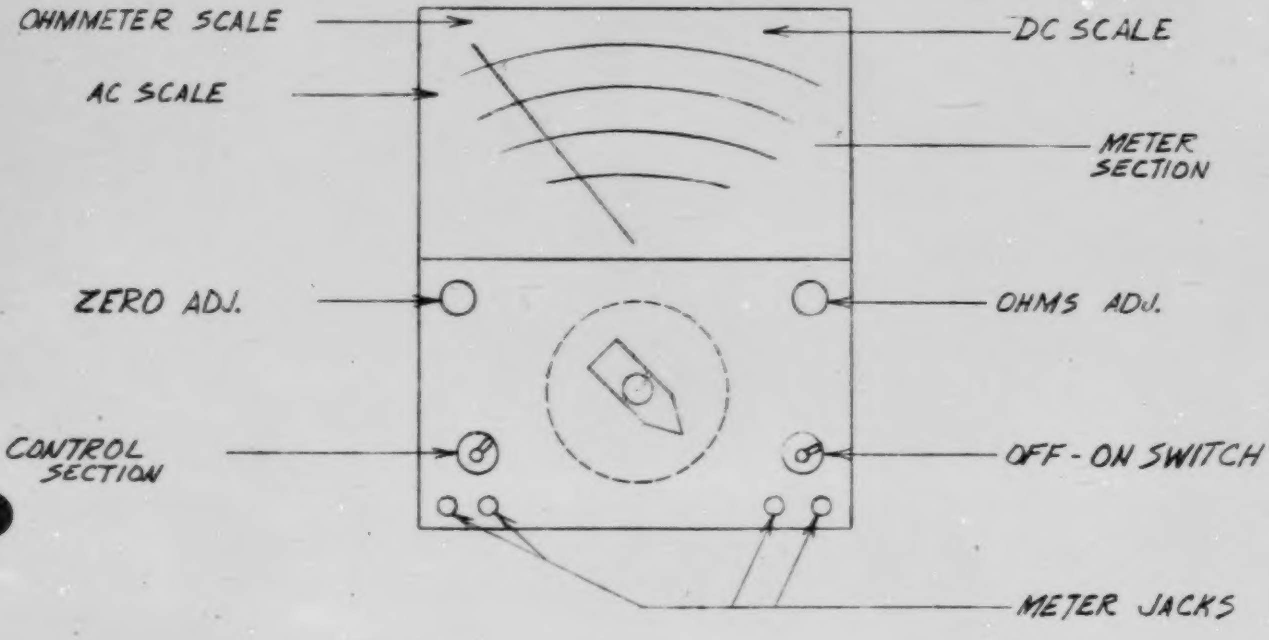
STUDENT HANDOUT #1
CHARACTERISTICS OF THE VOM

UNIT 01: METERS, PART I

THE MULTIMETER SERVES AS MORE THAN ONE TYPE OF METER. THE MICRONTA MULTITESTER USED IN THIS PROGRAM CAN BE USED AS AN AC VOLTMETER, A DC VOLTMETER, AN OHMMETER, OR A DC MILLIAMMETER. IT IS BUT ONE OF THE MANY DIFFERENT MULTIMETERS IN USE TODAY. THE MULTIMETER IS COMMONLY CALLED A VOLT-OHM-MILLIAMMETER OR SIMPLY A VOM.

ANSWER QUESTION #1 AT THE END OF THIS HANDOUT.

THE VOM IS DIVIDED INTO SECTIONS. THE METER SECTION, USUALLY LOCATED AT THE TOP, AND THE CONTROL SECTION WHICH IS USUALLY LOCATED AT THE BOTTOM. SEE ILLUSTRATION BELOW.


OHMMETER SCALE
DC SCALE
AC SCALE
METER SECTION
ZERO ADJ.
OHMS ADJ.
CONTROL SECTION
OFF-ON SWITCH
METER JACKS

THE METER SECTION OF THE MICRONTA MULTITESTER HAS FOUR METER SCALES. THEY ARE THE OHMMETER SCALE, THE DC SCALE, THE AC SCALE, AND THE DECIBEL SCALE.

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

THE OHMMETER SCALE IS THE TOP SCALE ON THE METER. THIS SCALE IS USED FOR ALL RESISTANCE MEASUREMENTS. THIS SCALE IS PRINTED IN GREEN. IT READS FROM RIGHT TO LEFT. IT IS THE ONLY SCALE ON THE METER WHICH READS FROM RIGHT TO LEFT.

ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

THE DC SCALE IS THE SECOND SCALE FROM THE TOP. IT IS USED FOR ALL DC VOLTAGE AND CURRENT MEASUREMENTS. IT READS FROM LEFT TO RIGHT. IT IS PRINTED IN BLACK.

ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

THE THIRD SCALE IS THE AC SCALE. IT IS USED FOR ALL AC VOLTAGE MEASUREMENTS. THIS METER WILL NOT MEASURE AC CURRENT. THE AC METER SCALE IS PRINTED IN RED.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

THE BOTTOM SCALE HAS TWO PURPOSES. IT MEASURES VOLTAGE OUT-

PUT IN DECIBELS. A DECIBEL IS A MEASURE OF THE RATIO OF TWO VOLTAGES OR CURRENTS. WE WILL NOT USE THIS SCALE FOR THIS PURPOSE.

THE BOTTOM SCALE CAN ALSO BE USED TO CHECK THE CONDITION OF THE BATTERY INSIDE THE METER. THIS SCALE HAS A PORTION MARKED "BATTERY OK". WE WILL USE THIS SCALE ONLY FOR CHECKING THE BATTERY.

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

THE CONTROL SECTION OF THE MICRONTA MULTITESTER CONSISTS OF THREE (3) SWITCHES, FOUR (4) METER JACKS, A ZERO ADJUST KNOB, AND AN OHMS ADJUST KNOB. LOOK AT YOUR METER.

THE "RANGE" SWITCH IS THE ONE LOCATED IN THE CENTER OF THE CONTROL SECTION OF THE METER. IT SETS THE METER FOR USE AS A VOLTMETER, AN OHMMETER, OR AN AMMETER. IT OPERATES LIKE THIS:

1. WHEN YOU WANT TO USE THE METER AS AN OHMMETER PLACE THE "RANGE" SWITCH IN ANY OF THE FIVE (5) DIFFERENT OHMS POSITIONS. THESE OHMS POSITIONS ARE GREEN LIKE THE GREEN

OHMS SCALE AT THE TOP OF THE METER.

2. WHEN YOU WANT TO USE THE METER AS A DC VOLTMETER PLACE THE "RANGE" SWITCH IN ANY OF THE SEVEN (7) DC VOLTS POSITIONS. THESE POSITIONS ARE BLACK JUST LIKE THE DC SCALE.

3. WHEN YOU WANT TO USE THE METER AS A DC MILLIAMMETER PLACE THE "RANGE" SWITCH IN THE DC AMP POSITION. THE AMMETER USES THE SAME SCALE THAT IS USED FOR DC VOLTAGE MEASUREMENTS. THIS IS WHY THE DC AMMETER POSITIONS ARE ALSO BLACK.

4. WHEN YOU WANT TO USE THE METER AS AN AC VOLTMETER PLACE THE RANGE SWITCH IN THE AC VOLTS POSITION. THESE POSITIONS ARE RED JUST LIKE THE RED METER SCALE USED IN MEASURING AC VOLTAGES.

ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

ANOTHER SWITCH FOUND ON THE METER IS THE "OFF-BATTERY CHECK-ON" SWITCH. THIS IS A (3) THREE POSITION SWITCH. IT OPERATES LIKE THIS:

1. THE "OFF" POSITION DISCONNECTS THE METER MOVEMENT FROM THE CONTROL SECTION OF THE METER. THE METER SHOULD BE IN THE "OFF" POSITION ANYTIME IT IS NOT IN USE. REMEMBER, THE METER WILL NOT WORK WHEN IT IS IN THIS POSITION.

2. THE "BATTERY CHECK" POSITION IS USED ONLY TO CHECK THE BATTERY INSIDE THE METER. WHEN THE SWITCH IS IN THIS

POSITION, THE METER POINTER SHOULD MOVE UP-SCALE TO THE "BATTERY OK" AREA OF THE DECIBEL SCALE.

3. THE "ON" POSITION CONNECTS THE METER MOVEMENT TO THE CONTROL SECTION OF THE METER. THIS SWITCH MUST BE IN THE "ON" POSITION BEFORE THE METER CAN BE USED.

ANSWER QUESTION #8 AT THE END OF THIS HANDOUT.

THE LAST SWITCH ON THE METER IS CALLED THE "FUNCTION" SWITCH. IT IS A TWO (2) POSITION SWITCH ON THE LEFT SIDE OF THE METER. THE "FUNCTION" SWITCH IS USED TO REVERSE THE POLARITY OF THE METER. IT SHOULD BE LEFT IN THE (+DC-AC-Ω) POSITION. THE (- DC) POSITION IS USED ONLY WHEN THE METER LEADS HAVE BEEN CONNECTED TO A DC CIRCUIT OF REVERSED POLARITY.

ANSWER QUESTION #9 AT THE END OF THIS HANDOUT.

THERE ARE TWO (2) ADJUSTMENT KNOBS IN THE CONTROL SECTION.

1. THE "ZERO ADJUSTMENT" KNOB IS LOCATED ON THE LEFT SIDE OF THE CONTROL SECTION OF THE METER. IT IS USED TO SET THE POINTER TO ZERO ON THE AC AND DC METER SCALES. BEFORE MAKING ANY MEASUREMENTS, YOU SHOULD MAKE CERTAIN THAT THE POINTER IS SET TO ZERO.

ANSWER QUESTION #10 AT THE END OF THIS HANDOUT.

2. The "Ohms Adjustment" knob is used only when the meter is used as an ohmmeter. It sets the pointer at "Zero Ohms" before taking resistance measurements. "Zero Ohms" is on the right side of the meter.

Answer question #11 at the end of this handout.

There are four (4) meter jacks located at the bottom of the control section of the meter. They connect the test leads to the meter. This is how they are used.

1. The "Negative or Common Jack" is the one at the far left side of the meter. It is used for ALL measurements. The black lead should be plugged into this jack anytime the meter is used.
2. The "Positive V - - A" Jack is next to the common jack. This jack is used for the Red test lead. It is used for all volt, ohm, and ammeter measurements except voltage measurements over 300 volts.
3. The "AC1KV" Jack is used for AC voltage measurements over 300 volts. The red lead should be plugged into this jack. The meter will measure up to 1,000 volts (1KV) when this jack is used with the "Common" jack at the far left side of the meter.
4. The "DC1KV" Jack is used for measuring DC voltages over 300 volts.

Answer question #12 at the end of this handout.

STUDY QUESTIONS

1. A METER WHICH MEASURES VOLTS, OHMS, AND AMPERES IS SOMETIMES CALLED A ____________ METER OR SIMPLY A ________.

2. LIST THE NAMES OF THE FOUR SCALES USED ON THE MICRONTA MULTITESTER.

3. THE ONLY SCALE ON THE MICRONTA MULTITESTER WHICH READS FROM RIGHT TO LEFT IS THE __________ SCALE.

4. WHICH METER SCALE IS USED FOR DC VOLTAGE AND CURRENT MEASUREMENTS?

5. WHAT COLOR IS THE AC VOLTAGE SCALE?

6. FOR WHAT PURPOSE WILL WE USE THE BOTTOM DECIBEL SCALE?

7. WHAT IS THE PURPOSE OF THE "RANGE" SWITCH?

8. THE "BATTERY CHECK" SWITCH HAS TWO OTHER POSITIONS. WHAT ARE THE NAMES FOR THESE SWITCH POSITIONS?

9. THE "FUNCTION" SWITCH IS A TWO POSITION SWITCH. WHAT POSITION SHOULD IT BE IN FOR MEASURING AC VOLTAGE OR RESISTANCE?

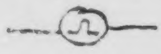
10. WHAT IS THE PURPOSE OF THE "ZERO ADJUST" KNOB?

11. THE "OHMS ADJUST" KNOB IS USED ONLY WHEN THE METER IS USED AS AN OHMMETER. WHAT DOES IT DO?

12. WHICH TWO JACKS ARE USED FOR MOST MEASUREMENTS OF THE VOM?

STUDENT HANDOUT #2
THE OHMMETER

Unit 01: Meters, Part I

The ohmmeter is used to measure the resistance of a circuit or device. The symbol for an ohmmeter is  . It can be used to determine the continuity of a circuit or to locate a defective component in the circuit.

Answer question #1 at the end of this handout.

Since resistance limits current, an open circuit would have an infinite resistance. Infinite resistance is when the resistance is so high that it cannot be measured. Infinite resistance is shown on the left side of the ohmmeter scale by this symbol ∞ .

Answer question #2 at the end of this handout.

The meter we will be using as an ohmmeter is the Micronta Multitester. You should have this meter to use as a reference while reading this handout.

Go get a Micronta Multitester.

The Micronta Multitester is like most other multimeters. It

IS CAPABLE OF MEASURING VOLTAGE, CURRENT AND RESISTANCE. ITS METER CONTROLS AND SCALES MAY VARY FROM OTHERS. NO TWO ARE EXACTLY ALIKE. WHEN A MULTIMETER IS USED AS AN AMMETER OR A VOLTMETER, IT RECEIVES THE NECESSARY CURRENT FROM THE CIRCUIT THAT IS BEING MEASURED. RESISTANCE CAN ONLY BE MEASURED IN A DEAD CIRCUIT. THERE MUST BE SOME OTHER SOURCE OF POWER TO PROVIDE THE CURRENT NECESSARY TO OPERATE THE METER.

ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

BATTERIES CHANGE WITH AGE. AN "OHMS ADJUSTMENT" KNOB IS PROVIDED SO THAT ADJUSTMENTS CAN BE MADE AS THE BATTERY GETS OLDER.

ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

IN USING THE OHMMETER, ALWAYS TAKE YOUR READINGS FROM DIRECTLY IN FRONT OF THE METER. A MIRROR IS PLACED IN THE SCALE TO HELP YOU DO THIS. WHEN YOU ARE DIRECTLY IN FRONT OF THE METER, YOU WILL NOT BE ABLE TO SEE THE REFLECTION OF THE POINTER IN THE MIRROR.

ALL RESISTANCES ARE READ FROM THE OHMS SCALE OF THE METER. THIS IS THE TOP SCALE. IT IS PRINTED IN GREEN. THE "RANGE SELECTOR" SWITCH (CENTER SWITCH) HAS FIVE SEPARATE SETTINGS FOR MEASURING RESISTANCE. THESE ARE X1, X10, X1K, X10K, AND X1M.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

WHEN THE RANGE SWITCH IS TURNED TO THE "X1" POSITION, THE RESISTANCE VALUES ARE READ DIRECTLY FROM THE SCALE. ON THE RESISTANCE SCALE THESE NUMBERS RUN FROM RIGHT TO LEFT. WHEN THE SWITCH IS TURNED TO THE "X10" POSITION, THE READINGS FROM THE SCALE MUST BE MULTIPLIED BY 10. ON THE "X1K' POSITION THE SCALE READINGS MUST BE MULTIPLIED BY 1,000. FOR THE "X10K" POSITION THE SCALE READINGS MUST BE MULTIPLIED BY 10,000. FOR THE "X1M" POSITION THE READINGS MUST BE MULTIPLIED BY 1,000,000. BY SELECTING THE PROPER RANGE SWITCH SETTING, RESISTANCE VALUES FROM ZERO TO SEVERAL MILLION OHMS CAN BE MEASURED.

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

TO SET THE METER FOR USE AS AN OHMMETER, THE FUNCTION SWITCH (LOCATED ON THE LEFT SIDE) MUST BE PLACED IN THE "OHMS" POSITION. TURN THE FUNCTION SWITCH TO ITS RIGHT HAND POSITION. THE METER'S "OFF-ON" SWITCH MUST BE TURNED TO THE "ON" POSITION.

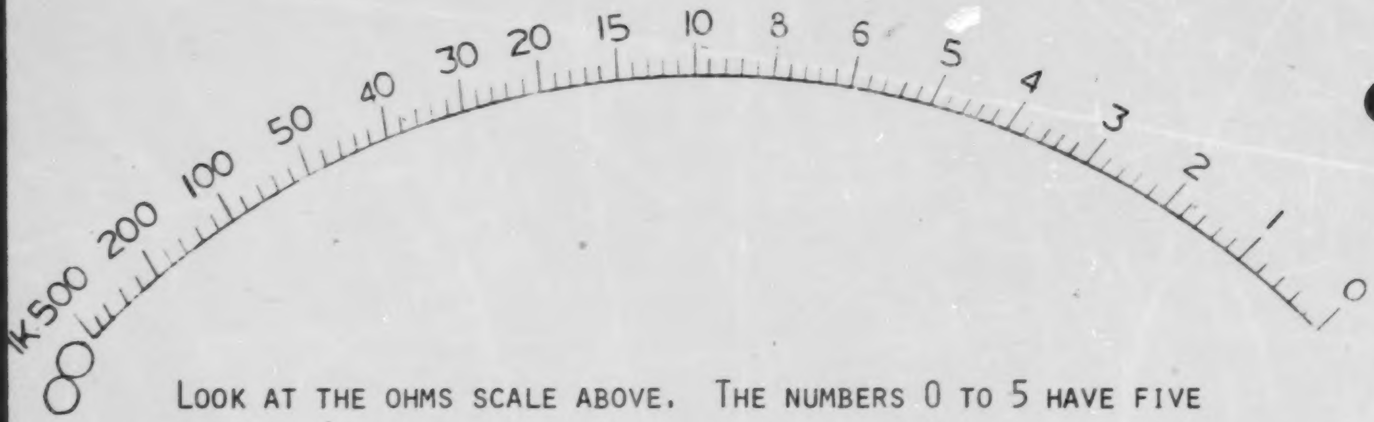
ANSWER QUESTIONS #7 AND #8 AT THE END OF THIS HANDOUT.

THE TEST LEADS ARE PLUGGED INTO THE TWO JACKS LOCATED IN THE LOWER LEFT-HAND CORNER OF THE METER. THESE METER JACKS ARE LABELED "-COM" AND "+ V- - A". THESE JACKS ARE USED FOR ALL

MEASUREMENTS EXCEPT WHEN MEASURING AC OR DC VOLTAGES OVER 300 VOLTS.

ANSWER QUESTION #9 AT THE END OF THIS HANDOUT.

THE OHMS SCALE IS DIFFERENT FROM ALL OF THE OTHER SCALES. FIRST, THE SCALE IS REVERSED. IT RUNS FROM RIGHT TO LEFT. SECOND, THIS SCALE IS NONLINEAR. NONLINEAR MEANS THAT THE DIVISIONS ARE NOT THE SAME ACROSS THE ENTIRE SCALE.



LOOK AT THE OHMS SCALE ABOVE. THE NUMBERS 0 TO 5 HAVE FIVE DIVISIONS BETWEEN THEM. THE NUMBERS 5 TO 10 HAVE ONLY TWO DIVISIONS BETWEEN THEM. THE CLOSER WE GET TO THE LEFT END OF THE SCALE, THE MORE CROWDED IT GETS. THE EXTREME RIGHT SIDE OF THE SCALE IS MARKED ZERO (0) OHMS. THE EXTREME LEFT SIDE IS MARKED AS INFINITY (∞). IF THE POINTER DEFLECTS ALL THE WAY TO THE RIGHT, IT INDICATES A VERY SMALL OR ZERO RESISTANCE. IF THE POINTER DOES NOT MOVE AT ALL FROM THE LEFT SIDE, THE RESISTANCE IS EITHER HIGH OR AN INFINITE RESISTANCE. AN OPEN CIRCUIT WILL GIVE THIS READING.

ANSWER QUESTION #10 AT THE END OF THIS HANDOUT.

BECAUSE OF CROWDING AT THE LEFT, OR HIGH, END OF THE SCALE, ACCURATE READINGS AT THIS END OF THE SCALE ARE ALMOST IMPOSSIBLE. HOWEVER, WITH FIVE (5) RESISTANCE RANGES, WE DON'T HAVE TO READ VALUES AT THIS END OF THE SCALE. WE CAN SIMPLY CHANGE TO THE NEXT RANGE TO TAKE OUR READING. THE MOST ACCURATE READINGS CAN BE TAKEN AT THE MIDDLE OF ANY SCALE. NEVER RELY ON A READING TAKEN TO THE LEFT OF 200 ON THE OHMS SCALE.

ANSWER QUESTION #11 AT THE END OF THIS HANDOUT.

TO GET READINGS THAT WILL BE CORRECT, THE OHMMETER MUST BE ZEROED EACH TIME YOU USE IT. TO ZERO THE METER, CONNECT THE TEST LEADS TOGETHER. THE POINTER WILL MOVE UP THE SCALE TO NEAR ZERO. IT MAY EVEN GO PAST ZERO. WITH THE LEADS CONNECTED TOGETHER, TURN THE "OHMS ADJUSTMENT" KNOB UNTIL THE POINTER IS ON ZERO.

WHEN YOU ARE READY TO TAKE A RESISTANCE READING, CHECK AGAIN TO MAKE CERTAIN THAT THE CIRCUIT IS DEAD. CONNECT THE LEADS ON EACH SIDE OF THE COMPONENT OR RESISTANCE YOU WISH TO MEASURE. IN OTHER WORDS, CONNECT THE METER IN PARALLEL, OR ACROSS THE COMPONENT. IF THE POINTER IS TOO FAR TO THE LEFT, CHANGE THE "RANGE" SWITCH TO A HIGHER RESISTANCE RANGE. BE SURE TO "REZERO" THE METER EACH TIME YOU CHANGE THE "RANGE" SWITCH. WHEN YOU HAVE YOUR READING, WRITE IT DOWN AND MULTIPLY

IT BY THE VALUE INDICATED ON THE "RANGE" SWITCH.

ANSWER QUESTION #12 AT THE END OF THIS HANDOUT.

STUDY QUESTIONS

THE OHMMETER

1. DRAW THE SYMBOL USED TO REPRESENT AN OHMMETER.

2. HOW MUCH RESISTANCE WOULD AN OPEN CIRCUIT HAVE?

3. WHERE DOES THE OHMMETER GET ITS POWER?

4. WHAT ADJUSTMENT DOES THE OHMMETER HAVE BECAUSE THE BATTERY GETS OLDER?

5. HOW MANY OHMMETER RANGES DOES THE MICRONTA MULTITESTER HAVE?

6. YOU HAVE YOUR OHMMETER "RANGE" SWITCH SET ON THE "X1K SETTING, AND THE POINTER GIVES A 5 READING. HOW MUCH RESISTANCE ARE YOU MEASURING?

7. IN ORDER TO MEASURE RESISTANCE, IN WHAT POSITION SHOULD THE "FUNCTION" SWITCH BE?

8. WILL THE METER MEASURE RESISTANCE IF THE "OFF-ON" SWITCH IS IN THE "BATTERY CHECK" POSITION?

9. THE TWO JACKS USED FOR MEASURING RESISTANCE ARE LOCATED IN THE BOTTOM (LEFT/RIGHT) CORNER OF THE METER.

10. IN WHAT TWO WAYS DOES THE OHMMETER SCALE DIFFER FROM THE OTHER SCALES?

11. ON WHICH END OF THE OHMMETER SCALE IS THE MOST ACCURATE READING OBTAINED?

12. WHAT MUST YOU DO TO YOUR READING TO DETERMINE HOW MUCH RESISTANCE YOU ARE MEASURING?

EXPERIMENT #1

THE OHMMETER

REQUIRED MATERIAL:

1 - Meter, VOM

1 - Assortment of 10 Resistors

PROCEDURE:

1. Get all required material and find a place to work.
2. Set the VOM for operation as an ohmmeter.
3. Arrange the components on the table. Place a piece of scrap paper under each component.
4. Measure the resistance of each component. Record your readings on scrap paper under each component.
5. Have the instructor check your measurements.
6. Turn the meter off.
7. Return the meter and all material to the proper storage area.

Tips for using the ohmmeter:

1. Never connect the ohmmeter to an energized circuit. It has its own power source. Connecting it to an energized circuit will damage it.

2. KEEP YOUR FINGERS OFF THE TEST PROBES. YOUR BODY HAS RESISTANCE AND WILL CAUSE AN ERROR IN YOUR READING.

3. USE A "RANGE" SWITCH POSITION THAT WILL GIVE AN INDICATION BETWEEN "0" AND 200 OHMS. THIS IS THE EASIEST PART OF THE SCALE TO READ.

4. ALWAYS ZERO THE METER EACH TIME YOU CHANGE THE "RANGE" SWITCH SETTING. IF IT WILL NOT ZERO, CHECK FOR A BAD BATTERY.

5. POSITION YOURSELF IN FRONT OF THE METER WHEN READING IT.

6. REMEMBER TO MULTIPLY YOUR READING BY THE VALUE OF THE "RANGE" SWITCH SETTING.

STUDENT EXAMINATION #1

UNIT 01: METERS, PART I

1. WHICH WAY DOES THE OHMMETER SCALE READ ON THE MICRONTA MULTITESTER? CIRCLE THE CORRECT LETTER.

   A. LEFT TO RIGHT.
   B. RIGHT TO LEFT.

2. THE MICRONTA MULTITESTER HAS A "ZERO ADJUSTMENT" KNOB. IT ALSO HAS AN "OHMS ADJUSTMENT" KNOB. BECAUSE THE "OHMS ADJUSTMENT" KNOB SETS THE POINTER AT ZERO OHMS, YOU DO NOT NEED TO USE THE "ZERO ADJUSTMENT" KNOB WHEN YOU USE THE MICRONTA MULTITESTER AS AN OHMMETER. CIRCLE THE CORRECT LETTER.

   A. TRUE.
   B. FALSE.

3. HOW SHOULD YOU SET THE "FUNCTION" SWITCH TO USE THE MICRONTA MULTITESTER AS AN OHMMETER?

4. FOR WHICH "RANGE" SWITCH SETTING ON THE MICRONTA MULTITESTER CAN YOU READ DIRECTLY FROM THE SCALE? CIRCLE THE CORRECT LETTER.

   A. X1K
   B. X1
   C. X10

5. IF YOU HAVE THE MICRONTA MULTITESTER SET ON THE X10 SCALE AND YOU GET A READING ALMOST TO THE LEFT END OF THE SCALE, WHICH SETTING WOULD YOU SWITCH TO? CIRCLE THE CORRECT LETTER.

   A. X1K
   B. X1
   C. X10K

6. YOUR INSTRUCTOR WILL SHOW YOU A CIRCUIT. USE THE MICRONTA MULTITESTER AS AN OHMMETER TO CHECK RESISTANCE IN THE CIRCUIT. WRITE THE NUMBER OF OHMS HERE.

   ____________ OHMS.

7. YOUR INSTRUCTOR WILL GIVE YOU A RESISTOR. USE THE MICRONTA MULTITESTER TO CHECK IT. CHECK HERE IF IT IS "GOOD." _________ CHECK HERE IF IT IS "BAD." ______

STUDENT COMPETENCY SHEET

UNIT 01: METERS, PART II

COMPETENCY STATEMENT: USES THE MULTIMETER AS A VOLTMETER TO MEASURE AC AND DC VOLTAGE.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL USE THE MULTIMETER TO MEASURE AC AND DC VOLTAGES AND ANSWER QUESTIONS ABOUT ITS USE.

CONDITIONS: YOU HAVE 10 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARDS: ALL OF YOUR ANSWERS MUST BE CORRECT. ALL READINGS MUST BE WITHIN PLUS OR MINUS THE VALUE OF ONE GRADUATION ON THE VOLTMETER SCALE.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "THE AC VOLTMETER," AND A MICRONTA MULTITESTER. READ THE HANDOUT WHILE USING THE MULTITESTER AS REFERENCE. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.

2. GET INSTRUCTION SHEET, "AC VOLTMETER." READ THE SHEET AND COMPLETE ALL STEPS ON IT.

3. GET STUDENT HANDOUT #2, "THE DC VOLTMETER," AND THE MICRONTA MULTITESTER. READ THE HANDOUT WHILE USING THE MULTITESTER

AS A REFERENCE. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.

4. HAVE THE INSTRUCTOR SHOW YOU WHERE YOU CAN USE THE METER TO PRACTICE MEASURING DC VOLTAGES. TAKE THE MEASUREMENTS REQUIRED.

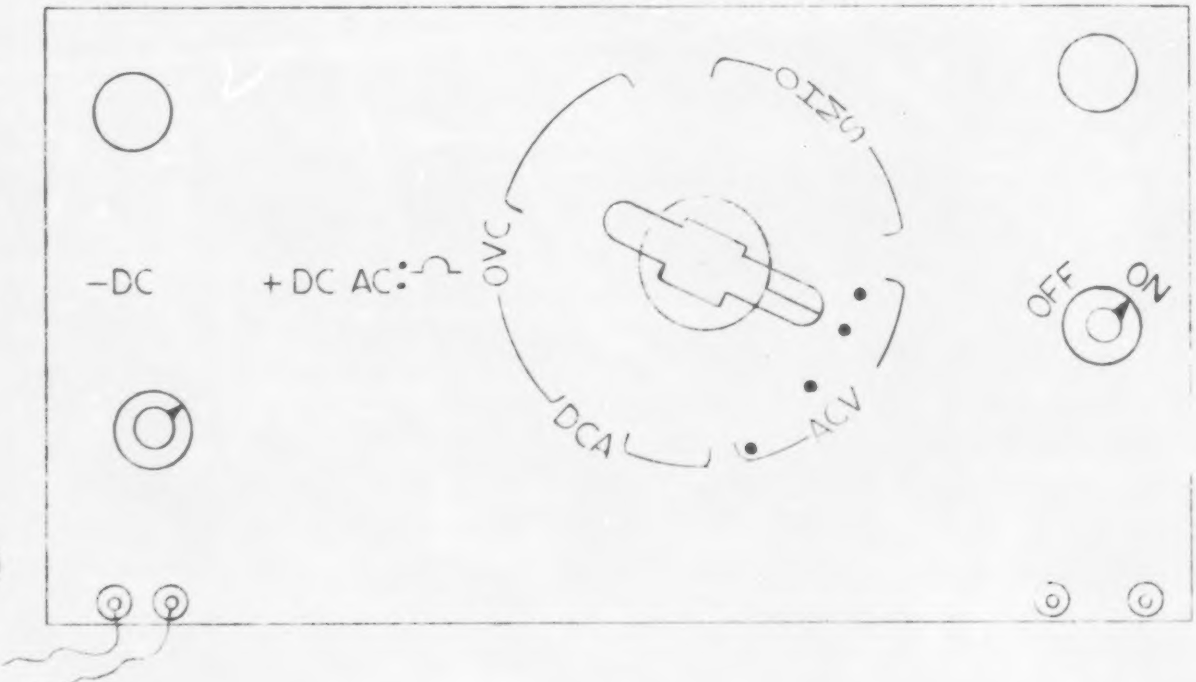
5. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
THE AC VOLTMETER

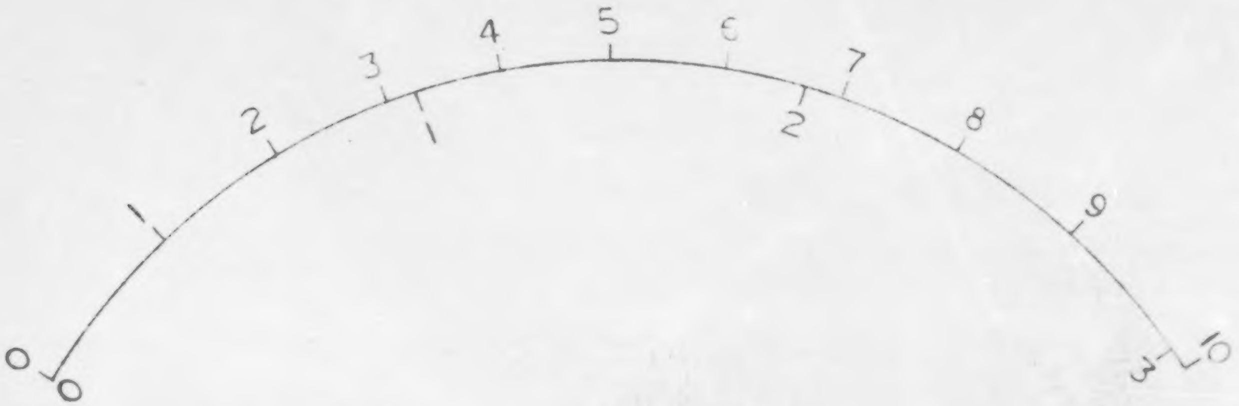
Unit 01: Meters, Part II

Now that you know what the VOM looks like, and can use it to measure resistance, let's see how we can use it to measure AC voltages.

In order to use the VOM as an AC voltmeter, the "Range" switch must be set at one of the AC volts positions. All other meter switches are set exactly as they were for measuring resistance. The "off-on" switch is set to the "On" position. The "Function" switch is set to its right hand position. The test leads are plugged into the two jacks at the bottom left side of the meter. See illustration below.



WHEN MEASURING AC VOLTAGES, THE RED SCALE (THIRD FROM TOP) IS USED. THERE ARE TWO SETS OF NUMBERS ALONG THE SCALE. ONE SET (0-10) IS ALONG THE TOP OF THE SCALE. THE OTHER SET (0-3) IS ALONG THE BOTTOM OF THE SCALE.



THE "RANGE" SWITCH TELLS US WHICH SCALE TO USE AND THE MAXIMUM VOLTAGE WE CAN MEASURE ON IT. IF THE "RANGE" SWITCH IS PLACED IN THIS 3 VOLT POSITION WE USE THE SET OF NUMBERS AT THE BOTTOM OF THE SCALE. IN THIS POSITION WE CANNOT MEASURE VOLTAGES GREATER THAN 3 VOLTS.

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

IF THE "RANGE" SWITCH IS PLACED AT THE 30 VOLT SETTING WE WILL BE ABLE TO MEASURE VOLTAGES UP TO 30 VOLTS. THE SAME METER SCALE IS USED FOR THIS SETTING OF THE "RANGE" SWITCH. THE 0 - 3 VOLT SCALE NOW BECOMES 0 - 30 VOLTS.

ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

IF THE "RANGE" SWITCH IS PLACED IN THE 300 VOLT POSITION, WE STILL USE THE NUMBERS, 0 - 3, ALONG THE BOTTOM OF THE SCALE. BUT LOOK HOW THEIR VALUES HAVE CHANGED! THE 1 IS NOW EQUAL TO 100. THE 2 IS EQUAL TO 200 VOLTS. AND THE 3 IS EQUAL TO 300 VOLTS.

ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

THE NUMBERS ALONG THE TOP OF THE SCALE ARE ONLY USED FOR THE 100 VOLT AND THE 1,000 VOLT SCALES.

VALUES FROM 0 TO 100 VOLTS CAN BE MEASURED BY PLACING THE "RANGE" SWITCH AT THE 100 VOLT POSITION. IN THIS POSITION, THE NUMBERS ALONG THE TOP OF THE SCALE HAVE VALUES OF 10, 20, 30, 40, 50, 60, 70, 80, 90, AND 100 VOLTS.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

IF THE VOLTAGES GREATER THAN 300 VOLTS ARE TO BE MEASURED, THE "RANGE" SWITCH MUST BE PLACED IN THE 300 VOLT POSITION. THE POSITIVE TEST LEAD MUST ALSO BE CHANGED TO THE "AC 1KV" METER JACK.

WHEN THE METER IS SET TO MEASURE UP TO 1000 VOLTS, THE UPPER SET OF NUMBERS ON THE METER SCALE IS USED. THE VOLTAGE VALUE OF EACH NUMBER BECOMES 100, 200, 300, . . . 800, 900, AND 1000 VOLTS.

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

SELECTING THE PROPER SETTING FOR THE "RANGE" SWITCH IS VERY IMPORTANT. THE METER MAY BE PERMANENTLY DAMAGED IF YOU TRY TO MEASURE 30 VOLTS ON THE 3 - VOLT SCALE.

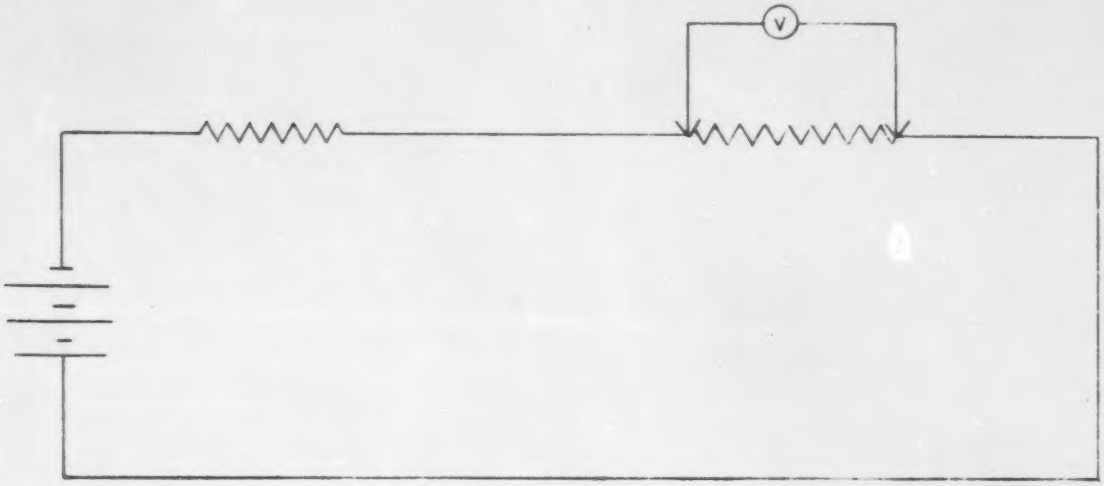
USING THE PROPER SETTING IS EASY IF YOU KNOW THE APPROXIMATE VOLTAGE YOU ARE MEASURING. YOU JUST MAKE SURE THE SCALE YOU USE IS ABLE TO MEASURE THE APPROXIMATE VOLTAGE.

IF YOU ARE GOING TO MEASURE AN UNKNOWN VOLTAGE, BEGIN WITH THE LARGEST SCALE ON THE METER. IF IT IS TOO LARGE, CHANGE TO THE NEXT SMALLER SCALE. CONTINUE TO CHANGE TO A LOWER SCALE, UNTIL YOU FIND THE ONE THAT WILL GIVE A READING AT APPROXIMATELY MID-SCALE.

ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

USING THE VOLTMETER:

TO MEASURE VOLTAGE THE VOLTMETER IS CONNECTED IN PARALLEL (ACROSS) THE CONPONENT THAT YOU ARE MEASURING. SEE BELOW.



THIS IS THE SAME WAY YOU CONNECTED THE OHMMETER WHEN YOU WERE MEASURING RESISTANCE. THE BIG DIFFERENCE IS THE CIRCUIT IS "LIVE".

BEFORE USING THE METER TO CHECK VOLTAGE, ALWAYS RE-CHECK THE SWITCHES OF THE METER. THE "RANGE" SWITCH SHOULD BE SET AT THE PROPER AC VOLTS SETTING FOR THE VOLTAGE YOU ARE MEASURING. THE "FUNCTION" SWITCH SHOULD BE IN THE RIGHT "AC" POSITION. AND, THE METER "OFF-ON" SWITCH MUST BE IN THE "ON" POSITION.

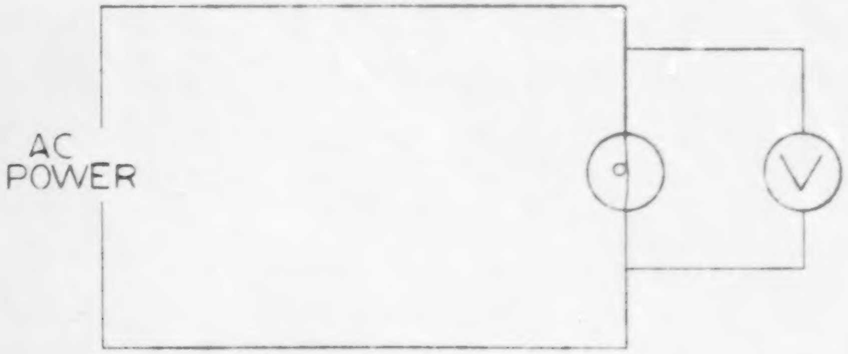
KEEP YOUR FINGERS OFF THE TEST PROBES WHEN USING THE VOLTMETER. REMEMBER, YOU ARE MEASURING VOLTAGE. IF YOUR FINGERS MAKE

CONTACT WITH THE LIVE PART OF THE PROBES, YOU MAY GET A SHOCK.

WHEN MEASURING VOLTAGE ON LIVE TERMINALS WHICH ARE CLOSE TOGETHER, BE CAREFUL NOT TO SHORT THE TERMINALS TOGETHER. SHORT-CIRCUITING TWO LIVE TERMINALS MAY CAUSE DAMAGE TO THE EQUIPMENT, OR IT MAY BURN UP THE TEST PROBES ON YOUR METER.

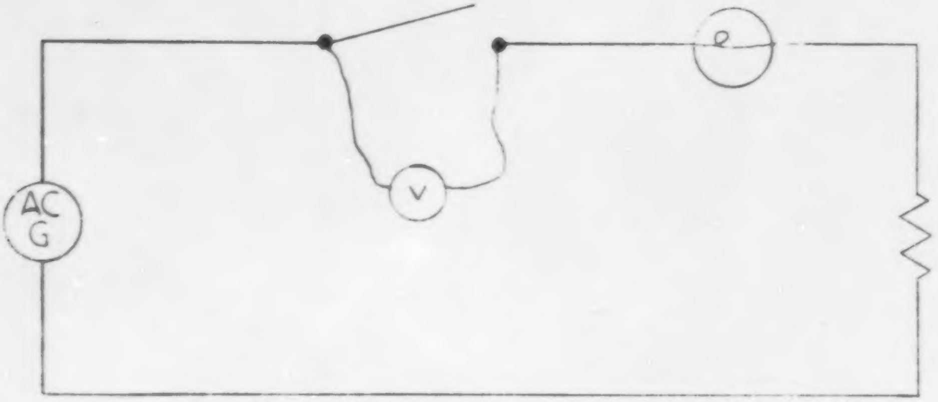
ANSWER QUESTION #8 AT THE END OF THIS HANDOUT.

A VOLTMETER, OR ANY METER, CANNOT TELL YOU IF A CIRCUIT OR COMPONENT IS GOOD OR BAD. YOU MUST DO THIS. THE METER WILL ONLY SHOW THE VOLTAGE THAT YOU HAVE BETWEEN TWO POINTS IN A CIRCUIT. YOU MUST KNOW WHERE TO CHECK FOR VOLTAGE, AND WHAT VOLTAGE SHOULD BE AT THE POINT YOU ARE CHECKING.

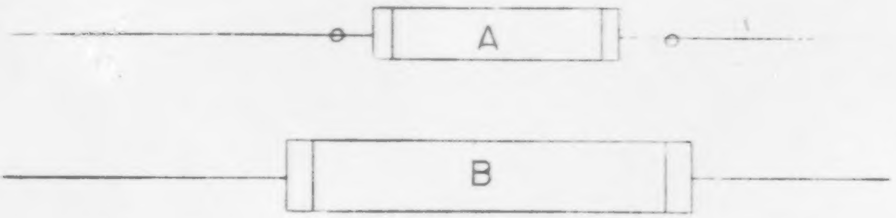


IN THE CIRCUIT ABOVE THE LIGHT IS OUT. YOU CONNECT YOUR VOLTMETER IN PARALLEL WITH THE LIGHT. YOUR VOLTMETER INDICATES THAT 120 VOLTS EXIST BETWEEN THE TERMINALS OF THE LIGHT. THIS TYPE OF VOLTMETER CHECK TELLS US THAT THE LIGHT IS BURNED OUT. THE METER DOES NOT TELL US WHY THE LIGHT BURNED OUT, NEITHER

DOES IT TELL US IF THE VOLTAGE IS THE CORRECT AMOUNT. CHECKING THE MAINTENANCE MANUAL WILL TELL US IF THE VOLTAGE WE MEASURE IS CORRECT. CHECKING THE VOLTAGE RATING OF THE LIGHT WITH THE MANUAL WILL TELL US IF THE LAMP IS THE CORRECT SIZE.



CONNECTING A VOLTMETER ACROSS THE TERMINALS OF AN OPEN SWITCH WILL TELL US IF WE HAVE A COMPLETE CIRCUIT. (SEE DIAGRAM ABOVE) IF THE CIRCUIT IS COMPLETE, THE VOLTMETER SHOULD GIVE AN INDICATION EQUAL TO THE SUPPLY VOLTAGE. IF THE CIRCUIT IS NOT COMPLETE, THE METER WOULD READ ZERO.



FUSES CAN BE CHECKED WITH A VOLTMETER. (SEE ILLUSTRATION ABOVE) TO CHECK FUSE "A" CONNECT YOUR VOLTMETER LEADS AS FOLLOWS: CONNECT ONE VOLTMETER LEAD TO THE "LINE" SIDE OF FUSE "B".

Connect the other lead to the "Load" side of Fuse "A". If fuse "A" is good, the meter will indicate the full voltage of the power source. If fuse "A" is bad, current cannot get through it. The voltmeter will read zero volts. Reverse your leads to check the other fuse. Connect one lead to the line side of fuse "A" and the other lead to the load side of fuse "B".

Safety precautions:

1. Keep your fingers off the meter probes when taking voltage measurements.
2. Be careful not to short out energized terminals with the meter probes.
3. When taking measurements over 500 volts, disconnect the power. Make your meter connections with the power off. Separate your test leads so that they do not cross. Stand clear of the meter and leads. Turn the power on just long enough to read the meter. Turn the power off before you disconnect the meter. The meter is capable of measuring up to 1,000 volts. The leads may or may not be, depending on their condition.

STUDY QUESTIONS
THE AC VOLTMETER

1. WHERE IS THE "RANGE" SWITCH SET FOR MEASURING AC VOLTAGE?

2. WHAT IS THE MAXIMUM VOLTAGE THAT WE CAN MEASURE ON THE 3 VOLT RANGE?

3. THE VOLTMETER INDICATES 2 VOLTS, BUT YOU HAVE THE "RANGE" SWITCH SET ON THE 30 VOLT RANGE. HOW MUCH VOLTAGE ARE YOU MEASURING?

4. WHAT IS THE MAXIMUM AMOUNT OF VOLTAGE THAT YOU CAN MEASURE ON THE 300 VOLT RANGE?

5. WITH THE "RANGE" SWITCH ON THE 100 VOLT SCALE, YOUR METER READS 6. HOW MUCH VOLTAGE ARE YOU MEASURING?

6. IN ORDER TO MEASURE VOLTAGES HIGHER THAN 300 VOLTS, THE POSITIVE TEST LEAD MUST BE CHANGED TO THE ____________ METER JACK.

7. WHEN MEASURING UNKNOWN VOLTAGES, YOU SHOULD BEGIN BY USING THE (SMALLEST/LARGEST) SCALE FIRST.

8. WHAT ARE TWO HAZARDS IN USING THE VOLTMETER?

STUDENT HANDOUT #2

THE DC VOLTMETER

UNIT 01: METERS, PART II

THE MICRONTA MULTITESTER CAN BE USED FOR MEASURING DC VOLTAGES AS WELL AS AC VOLTAGE AND RESISTANCE.

GO GET A MICRONTA MULTITESTER TO USE AS A REFERENCE WHILE READING THIS HANDOUT.

TO SET THE MULTIMETER FOR USE AS A DC VOLTMETER, THE SWITCH SETTINGS ARE THE SAME AS THEY WERE FOR MEASURING AC VOLTAGES EXCEPT FOR THE "RANGE" SWITCH. OF COURSE, YOU ALREADY KNOW THAT THE "RANGE" SWITCH HAS TO BE IN ONE OF THE DC VOLT POSITIONS.

ANSWER QUESTION #1 AT THE END OF THIS HANDOUT.

THE SCALE USED FOR DC VOLTAGE MEASUREMENTS IS THE DC SCALE. IT IS THE BLACK ONE (SECOND FROM THE TOP).

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

THERE ARE TWO MORE DC VOLTS POSITIONS THAN AC VOLTS POSITIONS. THEY ARE THE 1-VOLT AND .3-VOLT RANGES.

ANSWER QUESTION #3 AND #4 AT THE END OF THIS HANDOUT.

THE MICRONTA MULTITESTER CAN BE USED TO MEASURE DC VOLTAGES UP TO 1000 VOLTS. MEASURING DC VOLTAGES OVER 300 VOLTS REQUIRES THAT THE "RANGE" SWITCH BE SET ON THE 300 VOLT RANGE. IT ALSO REQUIRES THE POSITIVE TEST LEAD TO BE PLUGGED INTO THE "DC 1KV" METER JACK ON THE RIGHT SIDE OF THE METER.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

THE DC VOLTMETER IS USED ON DC CIRCUITS FOR THE SAME PURPOSES THAT THE AC VOLTMETER WAS USED ON AC CIRCUITS. THE SAME SAFETY PRECAUTIONS MUST BE FOLLOWED. THE DC SCALE IS READ JUST LIKE THE AC SCALE. THERE IS BUT ONE BIG DIFFERENCE IN THE PROCEDURE FOR CONNECTING THE METER LEADS TO A DC CIRCUIT. WHEN CONNECTING THE DC VOLTMETER TO A CIRCUIT, THE POLARITY OF THE CIRCUIT MUST BE OBSERVED. THIS MEANS THAT THE NEGATIVE METER LEAD MUST BE CONNECTED TO THE NEGATIVE SIDE OF THE CIRCUIT, AND THE POSITIVE METER LEAD MUST BE CONNECTED TO THE POSITIVE SIDE OF THE CIRCUIT. IF YOU CONNECT THE METER WITHOUT OBSERVING POLARITY, THE METER POINTER WILL TRY TO MOVE BACKWARD. THIS MAY DAMAGE THE METER.

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

SOMETIMES IT IS IMPOSSIBLE TO DETERMINE THE POLARITY OF A

CIRCUIT WITHOUT FIRST CONNECTING THE METER TO THE CIRCUIT. IN THIS TYPE SITUATION, USE THE HIGHEST SCALE, AND ONLY CONNECT THE METER LEADS MOMENTARILY. IF YOU DISCOVER THAT THE POLARITY IS INCORRECT, YOU CAN CORRECT THE SITUATION TWO WAYS. ONE WAY IS TO REVERSE THE METER TEST LEADS. ANOTHER WAY IS BY USING THE FUNCTION SWITCH. UP TO THIS TIME, WE HAVE ALWAYS USED THE METER IN THE "+ DC - AC -Ω" POSITION. WELL, SETTING THE SWITCH IN THE "- DC" POSITION REVERSES THE CONNECTIONS INSIDE THE METER. IN THIS POSITION, THE METER WILL MEASURE VOLTAGES OF REVERSED POLARITY. IT WILL NOT MEASURE RESISTANCE OR AC VOLTAGES.

ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

POINTS TO REMEMBER:

1. OBSERVE POLARITY WHEN USING A DC VOLTMETER.
2. USE THE PROPER "RANGE" SWITCH SETTING.
3. POSITION THE METER DIRECTLY IN FRONT OF YOU WHEN YOU READ THE SCALE.
4. READ THE CORRECT SCALE. THE 0 - 3 VOLT SCALE IS USED WHEN THE "RANGE" SWITCH IS SET ON THE .3, 3, 30, AND 300 VOLT POSITIONS. THE 0 - 10 VOLT SCALE IS USED FOR THE 1, 10, 100, AND 1,000 VOLT POSITIONS.

STUDY QUESTIONS

DC VOLTMETER

1. HOW MANY "RANGE" SWITCH SETTINGS ARE THERE FOR MEASURING DC VOLTAGE?

2. HOW IS THE DC SCALE LIKE THE AC SCALE?

3. WHAT IS THE MAXIMUM VOLTAGE THAT CAN BE MEASURED ON THE 3 VOLT RANGE?

4. WHAT IS THE MAXIMUM VOLTAGE THAT CAN BE MEASURED ON THE 1 VOLT RANGE?

5. IF VOLTAGES HIGHER THAN 300 VOLTS ARE TO BE MEASURED, THE POSITIVE LEAD MUST BE PLUGGED INTO THE ____________ METER JACK.

6. WHAT HAPPENS WHEN A DC VOLTMETER IS CONNECTED TO A CIRCUIT WITH REVERSED POLARITY?

7. WHICH POSITION OF THE "FUNCTION" SWITCH WILL PERMIT THE METER TO BE USED WHEN CONNECTED AT REVERSED POLARITY?

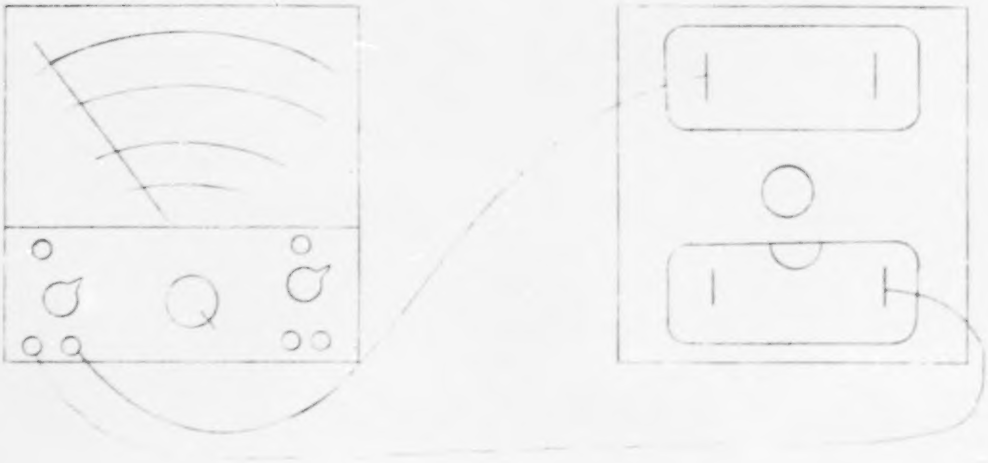
INSTRUCTION SHEET
AC VOLTMETER

Unit 01: Meters, Part II

This activity will permit you to become familiar with the use of the VOM as an AC voltmeter. Be sure to observe all safety precautions in order to protect both you and the meter.

Get a Micronta VOM and complete the following exercises:

1. Measure the voltage at a wall receptacle in the training area. To do this,
   A. Locate a live (energized) receptacle
   B. Set the "Range" switch of the VOM to an appropriate AC voltage scale. What voltage do you estimate you will be measuring?
   C. Plug the probes of the meter leads into the receptacle. See illustration below. Read the meter scale.



2. YOUR NEXT VOLTAGE MEASUREMENT WILL BE TAKEN FROM THE AC BELT-STARTER TRAINING PANEL.

   A. LOCATE THE CORRECT PANEL. ASK THE INSTRUCTOR FOR ASSISTANCE IF NEEDED.

   B. FOLLOW THE POWER SUPPLY CABLE TO WHERE IT CONNECTS TO THE PANEL. IT SHOULD TERMINATE AT A CIRCUIT BREAKER.

   C. HOW MANY WIRES ARE THERE IN THE CABLE? WHAT VOLTAGES DO YOU EXPECT TO MEASURE? .

   D. CAREFULLY CONNECT THE METER PROBES TO THE TERMINALS OF THE CIRCUIT BREAKER TO WHICH THE SUPPLY CABLE IS CONNECTED.

   E. READ THE METER. DID YOU USE THE CORRECT "RANGE" SWITCH SETTING?

3. YOUR LAST MEASUREMENT WILL BE TAKEN FROM ANOTHER TRAINING PANEL. IT IS THE AC/DC PANEL, AND IS THE LARGEST ONE IN THE TRAINING AREA. YOU MUST NOTIFY THE INSTRUCTOR BEFORE TAKING ANY MEASUREMENTS ON THIS PANEL.

   A. NOTIFY THE INSTRUCTOR WHEN YOU ARE READY TO PROCEED.

   B. SET YOUR METER FOR VOLTAGE MEASUREMENTS UP TO 1,000 VOLTS AC.

   C. LOCATE THE PANEL, AND FOLLOW ITS POWER SUPPLY CORD TO WHERE IT TERMINATES ON THE PANEL.

   D. WITH THE POWER OFF, EXPLAIN TO THE INSTRUCTOR THE PROCEDURE YOU WOULD USE TO MEASURE THE VOLTAGE

APPLIED TO THE PANEL.

E. TURN THE POWER ON, AND MEASURE THE VOLTAGE AT THE BREAKER USING THE PROCEDURE PREVIOUSLY OUTLINED BY YOU.

F. RECORD YOUR MEASUREMENTS.

4. YOU HAVE THE INSTRUCTOR TO YOURSELF. NOW IS THE TIME TO HAVE A PERSONAL DISCUSSION TO CLEAR UP ANY QUESTIONS YOU MAY HAVE CONCERNING THE USE OF THE VOM AS AN AC VOLTMETER.

STUDENT EXAMINATION #1

UNIT 01: METERS, PART II

1. WHICH AC VOLTAGE READINGS CAN BE READ DIRECTLY FROM THE SCALE ON THE MICRONTA MULTITESTER? CIRCLE THE CORRECT LETTER.

   A. 0-30 VOLTS
   B. 0-300 VOLTS
   C. 0-3 VOLTS

2. IF YOU HAVE THE "RANGE" SWITCH ON MICRONTA SET AT 100 VOLTS, AC, AND YOU GET A READING OF 9, WHAT SHOULD YOU DO? CIRCLE THE CORRECT LETTER.

   A. CHANGE TO 30 VOLT SETTING
   B. CHANGE TO 300 VOLT SETTING

3. IF YOU USE A VOM TO CHECK DC VOLTAGE IN A CIRCUIT AND YOU GET A READING OF 220 VOLTS, YOU KNOW THAT THIS IS THE CORRECT VOLTAGE. CIRCLE THE CORRECT LETTER.

   A. TRUE
   B. FALSE

4. WHAT WILL HAPPEN TO THE METER POINTER IF YOU ARE USING THE MICRONTA MULTITESTER AS A DC VOLTMETER AND YOU CONNECT IT FOR THE WRONG POLARITY?

5. IF YOU HAVE THE "RANGE" SWITCH ON THE MICRONTA MULTITESTER SET ON 300 VOLTS AND YOU GET A SCALE READING OF 2, HOW MUCH VOLTAGE DO YOU HAVE? CIRCLE THE CORRECT ANSWER.

   A. 2 VOLTS
   B. 20 VOLTS
   C. 200 VOLTS

6. YOUR INSTRUCTOR WILL SHOW YOU AN AC CIRCUIT. USE THE MICRONTA MULTITESTER TO CHECK THE VOLTAGE IN THE CIRCUIT. WRITE THE NUMBER OF VOLTS HERE. ____________ VOLTS.

7. YOUR INSTRUCTOR WILL SHOW YOU A DC CIRCUIT. USE THE MICRONTA MULTITESTER TO CHECK THE VOLTAGE IN THE CIRCUIT. WRITE THE NUMBER OF VOLTS HERE. ________ VOLTS.

STUDENT COMPETENCY SHEET

UNIT 01: METERS, PART III

COMPETENCY STATEMENT: USES MULTIMETER (VOM) AS AN AMMETER.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT USING THE VOM AS AN AMMETER.

CONDITIONS: YOU WILL HAVE 10 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARDS: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "THE AMMETER," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
2. GET EXPERIMENT #1, "THE AMMETER," FROM THE INSTRUCTOR. DO ALL THE STEPS IN THE EXPERIMENT.
3. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

THE AMMETER

UNIT 01: METERS, PART III

SO FAR, WE HAVE LEARNED TO USE THE VOM AS AN OHMMETER TO MEASURE RESISTANCE AND AS AN AC OR DC VOLTMETER TO MEASURE VOLTAGE. NOW WE WILL DISCUSS ITS USE AS AN AMMETER, VARIOUS SWITCH SETTINGS, THE SCALE, AND THE PROPER WAY TO CONNECT IT TO A CIRCUIT.

THE MICRONTA VOM, LIKE MOST OTHERS, CAN BE USED TO MEASURE CURRENT IN MILLIAMPERES. IT CAN ONLY MEASURE DIRECT CURRENT. IT WILL NOT MEASURE ALTERNATING CURRENT. THE AMOUNT OF DC CURRENT THAT IT CAN MEASURE IS VERY SMALL. THE LARGEST AMOUNT OF CURRENT THAT THIS METER CAN MEASURE IS 3/10 OR 0.3 OF AN AMPERE. WHY SO SMALL?

WHEN MEASURING CURRENT WITH A METER THE CURRENT MUST GO THROUGH THE METER. THIS MEANS THAT IF THE METER WAS DESIGNED TO MEASURE 100 AMPERES ALL OF THE 100 AMPERES WOULD HAVE TO GO THROUGH THE METER. THE SIZE OF THE METER LEADS WOULD HAVE TO BE ABOUT THE SIZE OF YOUR PENCIL. WOULD THE SMALL CONTACTS OF THE "RANGE" SWITCH WITHSTAND 100 AMPERES? NO, THEY WOULD HAVE TO BE INCREASED TO ABOUT THE SIZE OF A CONTACTOR TIP! THE END RESULT WOULD BE A METER TOO LARGE TO CARRY AROUND.

THE SWITCH POSITIONS FOR MEASURING CURRENT, EXCEPT FOR THE

RANGE SWITCH, ARE THE SAME AS FOR MEASURING VOLTAGE. THESE ARE THE SWITCH POSITIONS. LOOK AT THE PICTURE AS YOU READ THIS.

A. THE OFF/ON SWITCH IS TURNED TO THE "ON" POSITION.

B. THE FUNCTION SWITCH IS PLACED IN THE "+ DC - AC - Ω " POSITION. OF COURSE, IF YOU GOOF UP AND DON'T OBSERVE CORRECT POLARITY, YOU COULD USE THE "- DC" POSITION.

C. THE POINTER SHOULD BE ZEROED ON THE DC SCALE.

D. THE METER JACKS IN THE LOWER LEFT CORNER ARE USED.

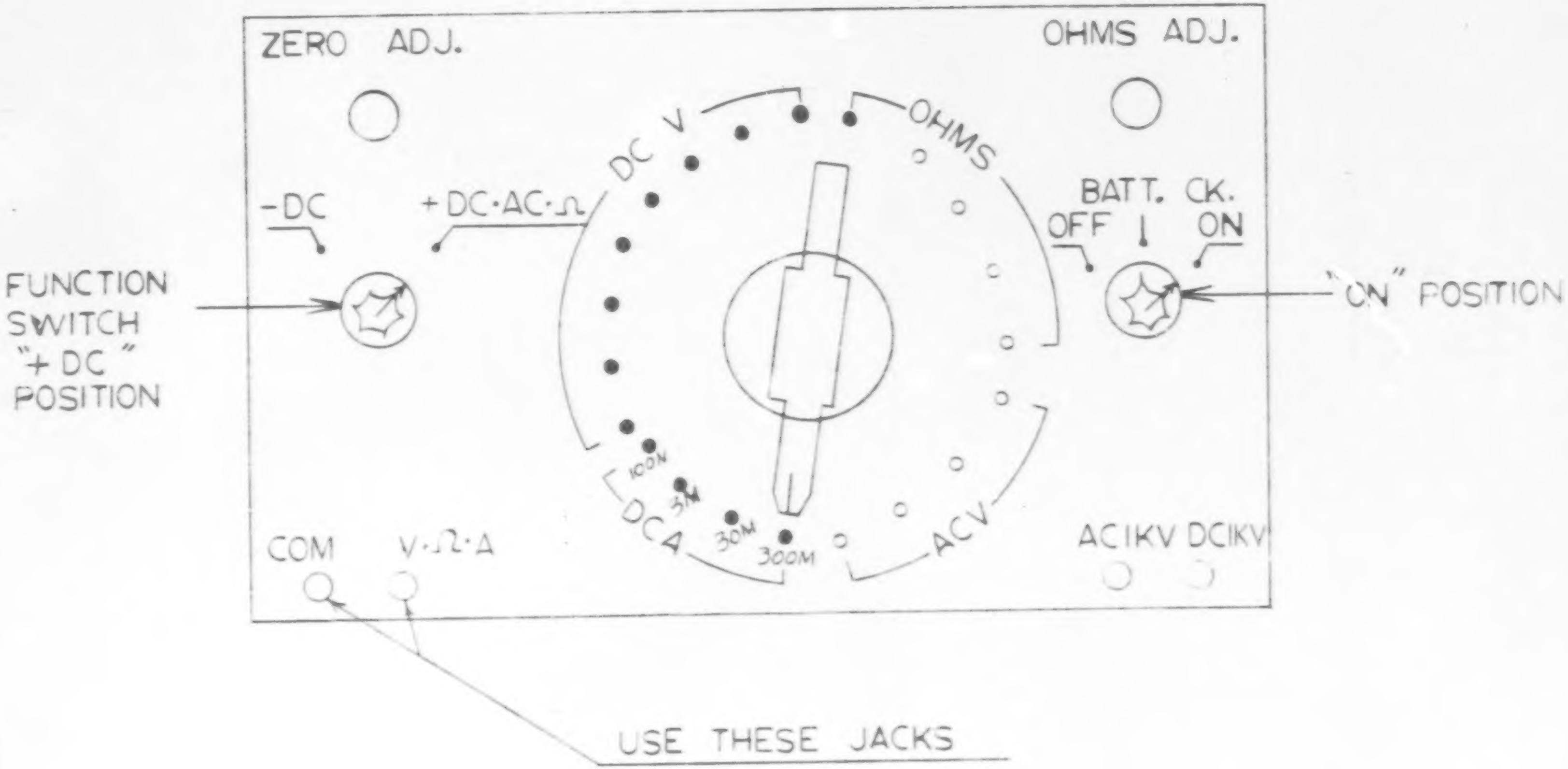
E. THE RANGE SWITCH IS PLACED ON ONE OF THE FOUR DC AMP POSITIONS, DEPENDING ON THE AMOUNT OF CURRENT YOU INTEND TO MEASURE.

1. THE 100 MICRO-AMPERE SCALE IS THE SMALLEST OF THE FOUR POSITIONS. IT PERMITS MEASUREMENTS OF CURRENT IN MILLIONTHS OF AN AMPERE.

2. THE 3 MILLIAMPERE SCALE IS USED FOR MEASURING CURRENTS BETWEEN ZERO, AND 3 MILLIAMPERES. A MILLI-AMPERE IS ONE-THOUSANDTHS OF AN AMPERE.

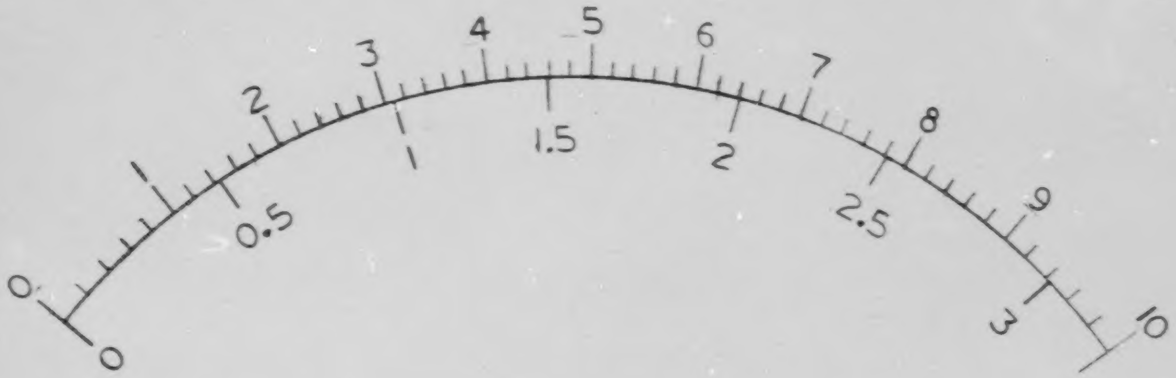
3. THE 30 MILLIAMPERE POSITION IS FOR MEASUREMENTS UP TO 30 MILLIAMPERES, OR 0.03 AMPERES.

4. THE 300 MILLIAMPERE POSITION ALLOWS MEASUREMENTS UP TO 0.3 OF AN AMPERE.


ZERO ADJ.
OHMS ADJ.
DC V
OHMS
-DC
+DC·AC·Ω
BATT. CK.
OFF
ON
FUNCTION SWITCH "+DC" POSITION
"ON" POSITION
100M
3M
30M
300M
DCA
ACV
COM
V·Ω·A
AC1KV
DC1KV
USE THESE JACKS

SWITCH POSITIONS FOR AMMETER

THE SAME METER SCALE THAT WAS USED FOR MEASURING DC VOLTAGE IS ALSO USED FOR MEASURING CURRENT. LOOK AT THE PICTURE BELOW. IT IS THE BLACK ONE, JUST UNDER THE MIRROR. IT IS READ THE SAME WAY. THE VALUE OF THE READING DEPENDS UPON WHICH RANGE SWITCH SETTING YOU ARE USING.



THE AMMETER IS ALWAYS CONNECTED IN SERIES WITH THE CIRCUIT YOU ARE MEASURING. NEVER CONNECT AN AMMETER IN PARALLEL WITH A CIRCUIT OR DEVICE. TO DO SO WOULD BE THE SAME AS CONNECTING A SOLID WIRE ACROSS THE CIRCUIT OR DEVICE AND SHORTING IT OUT. A GOOD WAY TO THINK OF AN AMMETER IS AS A WIRE LEAD WITH A TEST PROBE ON EACH END OF IT. YOU WOULD NEVER CONNECT A WIRE JUMPER ACROSS THE TERMINALS OF A BATTERY, A LAMP, OR A MOTOR, WOULD YOU? IF YOU CAN'T SAFELY CONNECT A WIRE JUMPER ACROSS TWO ELECTRICAL TERMINALS, THEN YOU CAN'T SAFELY CONNECT AN AMMETER ACROSS THEM EITHER.

IF YOU KNOW WHAT THE CURRENT IS SUPPOSED TO BE IN A CIRCUIT AN AMMETER CAN BE USED TO FIND OUT IF THE CURRENT FLOW IS NORMAL.

THE AMMETER CAN BE USED TO DETERMINE IF A CIRCUIT IS COMPLETE. BY CONNECTING THE METER TO THE TERMINALS OF AN OPEN SWITCH THE METER IS CONNECTED IN SERIES WITH THE CIRCUIT. THE METER COMPLETES THE CIRCUIT. A COMPLETE CIRCUIT WILL BE SHOWN BY A DEFLECTION OF THE METER POINTER.

SUMMARY.

ALTHOUGH THE AMMETER IS LIMITED IN ITS USE IT IS USEFUL IN TROUBLESHOOTING ELECTRONIC AND SOLID-STATE CIRCUITS. YOU HAVE JUST BECOME FAMILIAR WITH ITS USES, TYPE OF CONNECTIONS, AND SAFETY PRECAUTIONS.

REMEMBER THESE FEW FACTS:

A. ALWAYS CONNECT THE METER IN SERIES.

B. KEEP YOUR HANDS CLEAR OF THE METAL ENDS OF THE TEST PROBES.

C. IF YOU CONNECT AN AMMETER ACROSS THE TERMINALS OF AN OPEN SWITCH IT IS THE SAME AS CLOSING THE SWITCH. THIS MAY TURN ON A LIGHT, OR IT MAY START A MOTOR UP.

STUDY QUESTIONS

THE AMMETER

UNIT 01: METERS, PART III

1. CAN THE MICRONTA VOM BE USED TO MEASURE ALTERNATING CURRENT? WHY?

2. WHY IS THE MAXIMUM CURRENT THAT THE MICRONTA VOM CAN BE USED TO MEASURE SO SMALL?

3. WHAT IS THE ONLY DIFFERENCE IN SWITCH SETTINGS FOR DC VOLTAGE AND DC CURRENT MEASUREMENTS?

4. WHAT IS THE CORRECT WAY TO CONNECT THE MICRONTA VOM FOR USE AS AN AMMETER?

5. LIST THE HAZARDS INVOLVED IN USING AN AMMETER.

EXPERIMENT #1
THE AMMETER

UNIT 01: METERS, PART III

REQUIRED MATERIALS:

1 - VOM, MICRONTA

1 - BATTERY, 6 VOLT

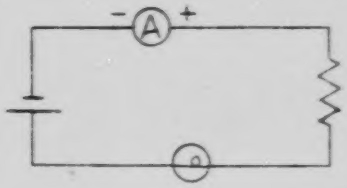
1 - RESISTOR, 10,000 OHM (VARIABLE)

1 - LAMP, 6 VOLT

2 - WIRE LEADS

PROCEDURE:

1. GET ALL OF THE REQUIRED MATERIALS AND A PLACE TO WORK.
2. SET THE VOM FOR AMMETER OPERATION. USE THE 300 MA SCALE.
3. SET THE POTENTIOMETER (VARIABLE RESISTOR) TO ITS MAXIMUM RESISTANCE.
4. MAKE THE CIRCUIT CONNECTIONS SHOWN BELOW.



5. DOES THE LAMP BURN? HOW MUCH CURRENT IS FLOWING?

6. DECREASE THE RESISTANCE GRADUALLY UNTIL THE LAMP BEGINS TO GLOW. WATCH YOUR METER AND DON'T LET IT GO PAST FULL-SCALE. HOW MUCH CURRENT IS FLOWING?

7. RETURN ALL MATERIALS AND EQUIPMENT TO THE PROPER STORAGE AREA.

STUDENT EXAMINATION #1

The Ammeter

Unit 01: Meters, Part III

________ 1. What is the maximum amount of DC current that can be measured with the Micronta VOM?

A. 300 Amperes

B. 300 Milliamperes

C. 3 Amperes

________ 2. What way do you connect an ammeter?

A. Series

B. Parallel

________ 3. What function switch setting is used for current measurements?

A. The (+ DC - AC - Ohm) position

B. The (- DC) position

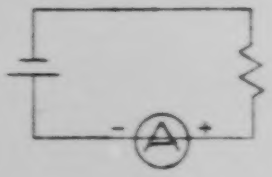
C. Either of the above

________ 4. What meter jacks are used for current measurement?

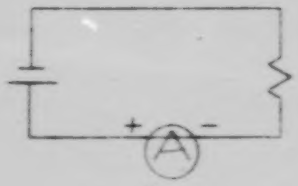
A. The two jacks in the lower left corner

B. The two jacks in the lower right corner

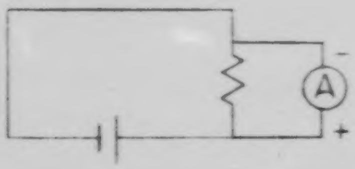
________ 5. Which cirucit below shows the ammeter connected correctly?



A



B



C

STUDENT COMPETENCY SHEET #1
RESISTORS

UNIT: 02 RESISTORS

COMPETENCY STATEMENT: IDENTIFIES RESISTORS AND THEIR SYMBOLS AND EXPLAINS THEIR USES AND CHARACTERISTICS.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL IDENTIFY RESISTORS BY HOW THEY LOOK, AND ANSWER QUESTIONS ABOUT THEIR SYMBOLS, USES, AND CHARACTERISTICS.

CONDITIONS: YOU HAVE 20 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GO TO A DISPLAY TABLE SET UP BY THE INSTRUCTOR. LOOK AT THE COMPONENTS ON THE TABLE. READ THE NAMES ON THE TAGS.
2. GET STUDENT HANDOUT #1, "RESISTORS," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
3. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
RESISTORS

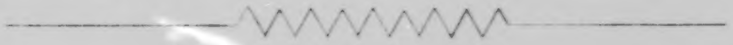
A RESISTOR IS A COMPONENT WHICH IS MADE TO HAVE A GIVEN RESISTANCE SO THAT IT WILL RESTRICT CURRENT FLOW. THIS LEADS TO ANOTHER QUESTION, "WHAT IS RESISTANCE?" RESISTANCE IS THE OPPOSITION TO CURRENT FLOW THROUGH AN ELECTRICAL CIRCUIT.

ANSWER QUESTION #1 AT THE END OF THIS HANDOUT.

THE BASIC UNIT OF MEASUREMENT FOR RESISTANCE IS THE OHM. ONE OF THE WAYS TO RATE A RESISTOR IS IN OHMS.

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

THE OHMIC VALUE OF A RESISTOR TELLS US HOW MUCH OPPOSITION TO CURRENT FLOW IT WILL CAUSE. FOR INSTANCE, A 100 OHM RESISTOR WILL CAUSE MORE OPPOSITION TO CURRENT FLOW THAN A 10 OHM RESISTOR. THE SYMBOL FOR A RESISTOR IS SHOWN BELOW.



ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

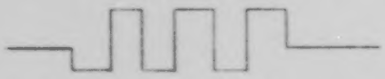
RESISTORS HAVE A POWER RATING TOO. THE POWER RATING OF A RESISTOR TELLS US HOW MUCH POWER IT CAN WITHSTAND BEFORE IT IS DAMAGED. THE POWER RATING FOR RESISTORS IS GIVEN IN WATTS. A 100 WATT RESISTOR CAN CONVERT 100 WATTS OF ELECTRICAL ENERGY INTO HEAT ENERGY AND NOT BE DAMAGED.

ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

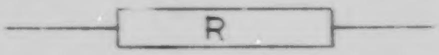
SINCE RESISTORS CONVERT ELECTRICAL ENERGY INTO HEAT ENERGY, THEY MUST BE ABLE TO GET RID OF IT. THEY MUST BE PHYSICALLY LARGE ENOUGH TO GIVE OFF THE HEAT. THIS MEANS THAT THE LARGER THE POWER RATING FOR A RESISTOR THE LARGER ITS PHYSICAL SIZE WILL BE.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

RESISTORS HAVING A LARGE POWER RATING ARE OFTEN CALLED POWER RESISTORS. TO TELL THEM FROM OTHER RESISTORS, THE SYMBOL IS CHANGED SLIGHTLY. BELOW IS THE ELEMENTARY AND SCHEMATIC SYMBOL USED FOR A POWER RESISTOR IN CIRCUITS OF MINING EQUIPMENT.



ELEMENTARY SYMBOL



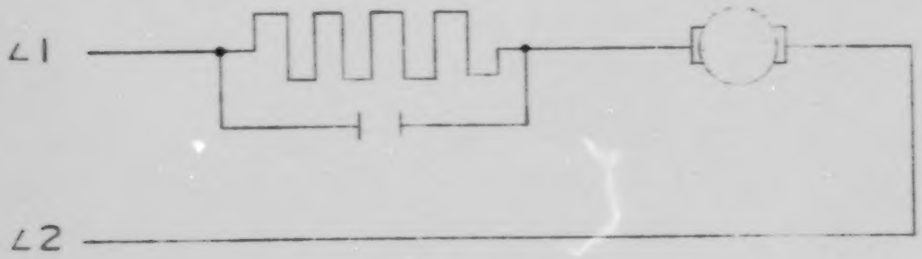
SCHEMATIC SYMBOL

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

RESISTORS COME IN TWO MAIN TYPES. THE TYPES ARE CARBON AND WIRE-WOUND. CARBON TYPE RESISTORS ARE MADE FROM A MIXTURE OF CARBON AND CLAY. THEY ARE INEXPENSIVE AND AVAILABLE IN MOST ANY OHMIC VALUE. CARBON RESISTORS HAVE TWO MAIN DISADVANTAGES. THEY HAVE SMALL POWER RATING AND THEIR RESISTANCE WILL CHANGE AS THEY GET OLDER. WIRE-WOUND RESISTORS ARE MORE ACCURATE THAN CARBON RESISTORS. THEIR RESISTANCE VALUE IS STABLE OVER LONG PERIODS OF TIME. THEY ARE AVAILABLE IN LARGE POWER RATINGS. THEIR MAIN DISADVANTAGE IS COST.

ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

AS A MINING ELECTRICIAN, YOU ARE MORE FAMILIAR WITH THE WIRE WOUND RESISTOR AND ITS USE AS A STARTING RESISTOR FOR A MOTOR.



A LARGE POWER RESISTOR IN THE CIRCUIT ABOVE IS CONNECTED IN SERIES WITH THE MOTOR ARMATURE. IT IS USED TO CONTROL (LIMIT OR RESTRICT) CURRENT FLOWING THROUGH THE ARMATURE TO A SAFE VALUE. WITHOUT IT, THE MOTOR WOULD BURN UP. NOTICE THAT THE CURRENT MUST FLOW THROUGH THE RESISTOR BEFORE IT CAN FLOW THROUGH THE ARMATURE OF THE MOTOR. SINCE THE RESISTOR OPPOSES CURRENT FLOW IT WILL PROTECT THE MOTOR FROM HIGH SURGES OF

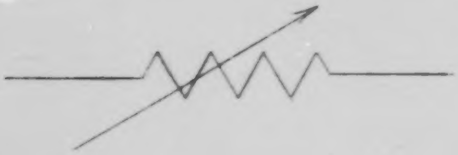
CURRENT DURING START UP. ONCE THE MOTOR HAS STARTED A TIMING DEVICE WILL OPERATE A CONTACTOR WHICH WILL BY-PASS THE RESISTOR.

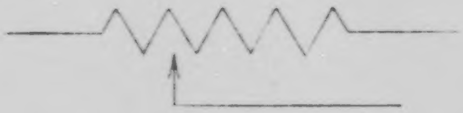
ANSWER QUESTION #8 AT THE END OF THIS HANDOUT.

LATER IN THIS COURSE, YOU WILL LEARN HOW ANOTHER DEVICE CALLED AN SCR CAN BE USED TO REPLACE A RESISTOR TO LIMIT THE STARTING CURRENT OF A MOTOR. YOU WILL LEARN HOW THE SCR CAN DO THIS WITHOUT WASTING POWER LIKE THE RESISTOR DOES.

ANSWER QUESTION #9 AT THE END OF THIS HANDOUT.

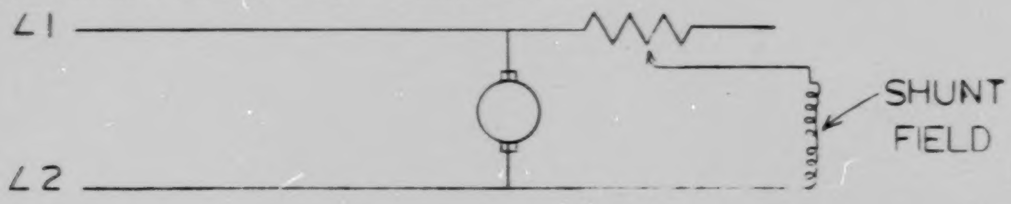
THERE ARE FIXED RESISTORS, AND THERE ARE VARIABLE RESISTORS. A FIXED RESISTOR IS ONE THAT HAS A FIXED RESISTANCE WHICH CANNOT BE CHANGED. A VARIABLE RESISTOR IS ONE THAT IS MADE SO THAT ITS RESISTANCE VALUE CAN BE CHANGED. A 1000 OHM VARIABLE RESISTOR CAN BE ADJUSTED TO ANY RESISTANCE BETWEEN ZERO AND 1000 OHMS. BELOW ARE TWO SYMBOLS USED FOR A VARIABLE RESISTOR.





ANSWER QUESTION #10 AT THE END OF THIS HANDOUT.

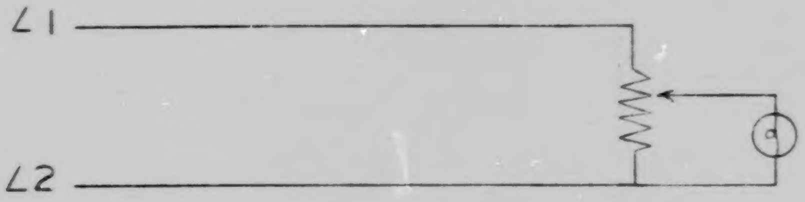
SOMETIMES RESISTORS ARE GIVEN SPECIAL NAMES FOR THE WAY THEY ARE USED IN A CIRCUIT. A RHEOSTAT IS A VARIABLE RESISTOR USED FOR CURRENT CONTROL. A COMMON USE FOR A RHEOSTAT IS AS A SPEED CONTROL DEVICE FOR A SHUNT MOTOR.



IN THE CIRCUIT ABOVE THE SPEED OF THE MOTOR IS CONTROLLED BY A RHEOSTAT. THE RHEOSTAT IS CONNECTED IN SERIES WITH THE SHUNT FIELD OF THE MOTOR. THERE ARE ONLY TWO ELECTRICAL CONNECTIONS TO THE RESISTOR.

ANSWER QUESTION #11 AT THE END OF THIS HANDOUT.

VARIABLE RESISTORS CAN ALSO BE USED TO CONTROL THE VOLTAGE IN A CIRCUIT. THIS IS POSSIBLE BECAUSE ANYTIME CURRENT FLOWS THROUGH A RESISTOR A VOLTAGE DROP WILL EXIST ACROSS THE RESISTANCE. WHEN A VARIABLE RESISTOR IS USED TO CONTROL VOLTAGE IT IS CALLED A POTENTIOMETER.



IN THE CIRCUIT ABOVE THE VOLTAGE OF THE LIGHT CAN BE ADJUSTED FROM ZERO TO FULL VOLTAGE SIMPLY BY CHANGING THE RESISTANCE VALUE OF THE POTENTIOMETER. THE POTENTIOMETER HAS THREE ELECTRICAL CONNECTIONS. REMEMBER THE RHEOSTAT HAD ONLY TWO. A POTENTIOMETER CAN BE USED AS A RHEOSTAT IF ONLY TWO OF ITS CONNECTIONS ARE USED. POTENTIOMETERS ARE USED FOR SPEED CONTROL SWITCHES IN MANY SOLID STATE MINING EQUIPMENT CONTROLS.

ANSWER QUESTION #12 AT THE END OF THIS HANDOUT.

SUMMARY

1. RESISTORS ARE DEVICES WHICH RESTRICT CURRENT FLOW IN A CIRCUIT.
2. RESISTORS HAVE AN ELECTRICAL RESISTANCE RATING WHICH IS IN OHMS.
3. RESISTORS HAVE A POWER RATING WHICH IS IN WATTS.
4. RESISTORS MAY BE CARBON OR WIRE-WOUND TYPE. EITHER TYPE MAY HAVE A FIXED VALUE OR THEY MAY BE VARIABLE.
5. A RHEOSTAT IS A VARIABLE RESISTOR USED TO PROVIDE CURRENT CONTROL.
6. A POTENTIOMETER IS A VARIABLE RESISTOR USED TO PROVIDE VOLTAGE CONTROL.
7. IN ANY CIRCUIT RESISTORS ACT AS AN OPPOSITION TO CURRENT FLOW. THIS BASIC PRINCIPLE IS USED IN ELECTRONIC CIRCUITS TO PROVIDE TIMING CONTROL. YOU WILL USE IT LATER IN THIS COURSE WHEN YOU STUDY FIRING CIRCUITS FOR THE SCR.

STUDY QUESTIONS
RESISTORS

1. Resistance is the ____________________ to current flow in a circuit.
2. The resistance rating of a resistor is given in ____________________.
3. Draw the symbol for a resistor.
4. The power rating of a resistor is given in ________________.
5. The physical ________________ of a resistor is a good indication of its power rating.
6. Draw the symbols commonly used to represent a power resistor.

Elementary Schematic

7. Two of the most common types of resistors are the carbon resistor and the ______________ ______________ resistor.
8. A resistor used to limit the starting current of a motor would be connected in ________________ with the motor armature.
9. Resistors waste power due to heating. Yes No

10. DRAW TWO SYMBOLS FOR A VARIABLE RESISTOR.

11. A ______________________ IS A VARIABLE RESISTOR USED TO PROVIDE CURRENT CONTROL TO THE CIRCUIT.

12. A ______________________ IS A VARIABLE RESISTOR USED TO PROVIDE VOLTAGE CONTROL TO THE CIRCUIT.

STUDENT EXAMINATION #1

UNIT: 02 RESISTORS

1. TO MEASURE RESISTANCE FOR A RESISTOR, WE WOULD MEASURE WHAT? CIRCLE THE CORRECT LETTER.
   - A. WATTS
   - B. OHMS
   - C. AMPS

2. DRAW THE SYMBOL FOR A RESISTOR.

3. WHICH IS MORE ACCURATE OVER A PERIOD OF TIME? CIRCLE THE CORRECT LETTER.
   - A. CARBON RESISTORS
   - B. WIRE-WOUND RESISTORS

4. DRAW TWO SYMBOLS FOR A VARIABLE RESISTOR.

5. WHICH OF THE FOLLOWING TYPES OF VARIABLE RESISTOR IS USED TO CONTROL CIRCUIT VOLTAGE? CIRCLE THE CORRECT LETTER.
   - A. POTENTIOMETER
   - B. RHEOSTAT

6. WHICH OF THE FOLLOWING TYPES OF VARIABLE RESISTOR IS USED TO CONTROL CIRCUIT VOLTAGE? CIRCLE THE CORRECT LETTER.
   - A. POTENTIOMETER
   - B. RHEOSTAT

7. THE INITIAL SURGE CURRENT WHICH RESULTS DURING MOTOR STARTING CAN BE CONTROLLED BY RESISTORS. CIRCLE THE CORRECT LETTER.
   - A. YES
   - B. NO

8. Most starting resistors used in mining equipment are: Circle the correct letter.

   A. Carbon type

   B. Wire-wound type

9. Any time there is current flowing through a resistor there is a voltage drop across the resistor. Circle the correct letter.

   A. Yes

   B. No

10. Go to the display table. Get a resistor. Take the resistor and the examination to the instructor.

STUDENT COMPETENCY SHEET #1

UNIT: 03 CAPACITORS, PART I

COMPETENCY STATEMENT: IDENTIFIES CAPACITORS AND SYMBOLS AND EXPLAINS CAPACITOR OPERATION

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. IDENTIFY A CAPACITOR BY WHAT IT LOOKS LIKE AND DRAW ITS SYMBOL.
2. ANSWER QUESTIONS ABOUT HOW A CAPACITOR OPERATES.

CONDITIONS: YOU HAVE 20 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GO TO THE DISPLAY TABLE SET UP BY THE INSTRUCTOR. LOOK AT ALL OF THE COMPONENTS. READ THEIR TAGS SO THAT YOU WILL KNOW WHAT CAPACITORS LOOK LIKE.
2. GO TO THE TRAINING PANELS. LOCATE A CAPACITOR ON ONE OF THE PANELS.
3. GET STUDENT HANDOUT #1, "CAPACITORS: IDENTIFICATION AND SYMBOL," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
4. GET EXPERIMENT #1, "CAPACITOR IDENTIFICATION AND SYMBOL," FROM THE INSTRUCTOR. DO ALL THE STEPS IN THE EXPERIMENT.

5. Get Student Handout #2, "Capacitor Operation and Testing," from the instructor. Read it. Answer the questions at the end of the handout.
6. Get Experiment #2, "Testing Capacitors," from the instructor. Do all of the steps in the experiment.
7. Tell the instructor when you are ready for the examination. Complete the examination.

STUDENT HANDOUT #1

CAPACITORS: IDENTIFICATION AND SYMBOL

Unit 03: Capacitors, Part 1

Capacitors have many uses ranging from power factor correction to filtering the output of DC power supplies. In this course we will limit our study to what a capacitor does, how it operates, and its uses in solid state controls on mining equipment.

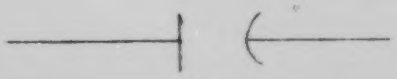
A capacitor is a device that is constructed in such a manner that it will store an electrical charge.

Answer question #1 at the end of this handout.

Capacitors are manufactured in many different shapes and sizes. Their size may range from the size of a pin head to several cubic feet. The canister type capacitor is one which you will become most familiar with as a mine electrician. If you should have to change a capacitor always replace it with one having the same voltage and capacitance rating.

Answer question #2 at the end of this handout.

The symbol used to represent a capacitor looks a lot like the symbol for a contactor. The symbol looks like this.



ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

CAPACITANCE IS A TERM WHICH TELLS HOW MUCH CHARGE A CAPACITOR WILL STORE. THE HIGHER THE CAPACITANCE RATING OF A CAPACITOR THE MORE ELECTRONS IT WILL STORE FOR EACH VOLT OF CHARGE. A LARGE POWER CAPACITOR WILL HOLD MORE ELECTRONS PER VOLT THAN A SMALL DISC TYPE CAPACITOR.

ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

CAPACITORS HAVE ELECTRICAL RATINGS WHICH TELL US SOMETHING ABOUT THEM. YOU RECALL FROM OUR STUDY ON RESISTORS, THAT RESISTORS HAVE RESISTANCE AND POWER RATINGS. WELL, CAPACITORS HAVE CAPACITANCE AND VOLTAGE RATINGS.

THE BASIC UNIT OF CAPACITANCE IS THE FARAD. HOW MUCH CAPACITANCE IS A FARAD? WELL, IT IS WHEN 6,250,000,000,000,000,000 ELECTRONS ARE MOVED FROM ONE OF THE CAPACITOR'S PLATES TO THE OTHER PLATE. A FARAD IS A VERY LARGE ELECTRICAL CHARGE. IN FACT, IT IS SO LARGE THAT THE CAPACITANCE FOR CAPACITORS IS GIVEN IN MICROFARADS. A MICROFARAD IS ONE-MILLIONTH OF A FARAD.

ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

THE VOLTAGE RATING OF A CAPACITOR TELLS US HOW MUCH VOLTAGE CAN BE APPLIED TO IT WITHOUT DAMAGE. THE VOLTAGE RATING OF A CAPACITOR IS ALWAYS GIVEN IN WORKING VOLTAGE DIRECT CURRENT

(WVDC). NEVER EXCEED THE VOLTAGE RATING OF A CAPACITOR. THIS WILL CAUSE PERMANENT DAMAGE. A DEFECTIVE CAPACITOR MUST BE REPLACED. IT CANNOT BE REPAIRED.

ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

CAPACITORS, LIKE RESISTORS AND BATTERIES, CAN BE CONNECTED IN SERIES OR PARALLEL IN ORDER TO OBTAIN A LARGER CAPACITANCE. WHEN SEVERAL CAPACITORS ARE CONNECTED TOGETHER AS A UNIT, THEY ARE SAID TO BE BANKED. THE ENTIRE UNIT IS CALLED A CAPACITOR BANK.

ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

STUDY QUESTIONS

CAPACITORS

1. A DEVICE THAT IS CAPABLE OF STORING AN ELECTRICAL CHARGE IS CALLED A ________________________.

2. THE TYPE OF CAPACITOR THAT IS USED IN MINING EQUIPMENT WHICH THE ELECTRICIAN WILL BE REQUIRED TO MAINTAIN IS THE ___________ TYPE.

3. DRAW THE SYMBOL FOR A CAPACITOR.

4. THE TERM WHICH REFERS TO THE ABILITY OF A CAPACITOR TO STORE AN ELECTRICAL CHARGE IS ____________________.

5. ALTHOUGH THE FARAD IS THE BASIC UNIT OF CAPACITANCE, MOST CAPACITORS ARE RATED IN MUCH SMALLER UNITS CALLED A _________ FARAD.

6. WVDC MEANS ____________ ____________ ____________ ____________.

7. WHEN SEVERAL CAPACITORS ARE CONNECTED TOGETHER AS A UNIT THEY ARE CALLED A CAPACITOR ___________________.

EXPERIMENT #1

CAPACITOR IDENTIFICATION AND SYMBOL

REQUIRED MATERIALS:

1 - Capacitor (any size)

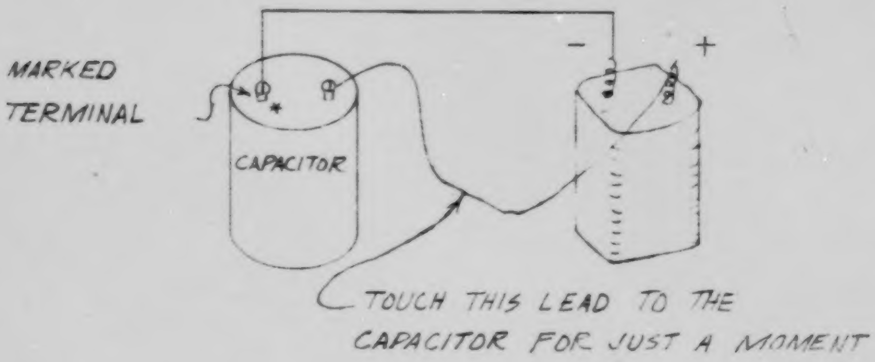
1 - Battery 6 volt

1 - VOM

1 - Wire leads

PROCEDURE:

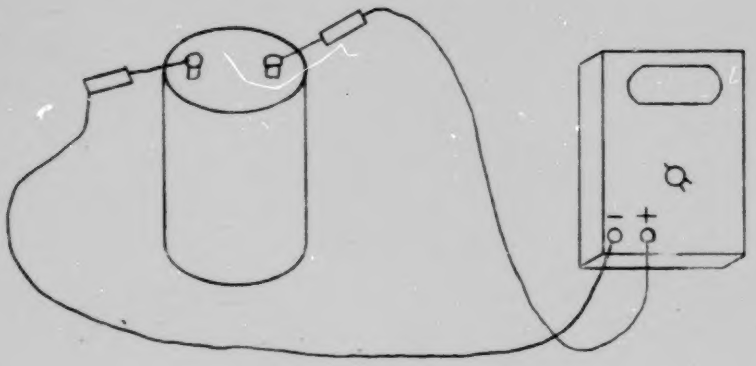
1. Get all of material and a place to work.
2. Mark one terminal of the capacitor with your pencil.
3. Charge the capacitor using the 6 volt battery. See illustration below.


MARKED TERMINAL
CAPACITOR
−
+
TOUCH THIS LEAD TO THE CAPACITOR FOR JUST A MOMENT

4. Disconnect the battery.

5. SET YOUR VOM METER TO MEASURE DC VOLTAGE. USE THE 10 VOLT SCALE. THIS WILL GIVE YOU A MID-SCALE READING.

6. CONNECT YOUR VOLTMETER TO THE CAPACITOR. BE SURE TO CONNECT THE NEGATIVE TERMINAL OF THE METER TO THE TERMINAL WHICH YOU MARKED. SEE BELOW.



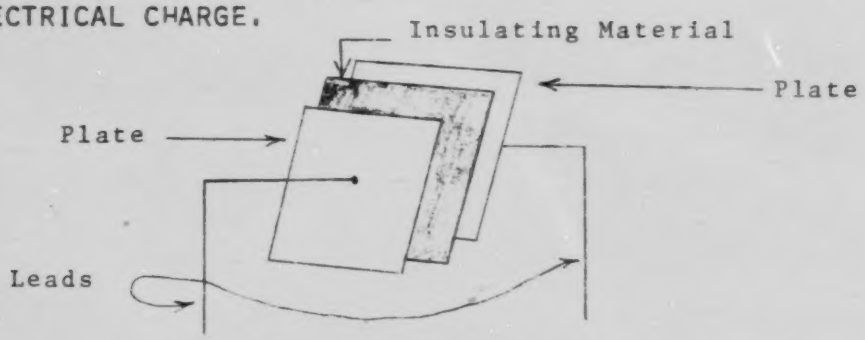
7. WHAT HAPPENED? WHY?

8. DRAW THE CIRCUITS SHOWN IN THIS EXPERIMENT USING SYMBOLS INSTEAD OF PICTURES.

STUDENT HANDOUT #2
CAPACITOR OPERATION AND TESTING

UNIT 03: CAPACITORS, PART 1

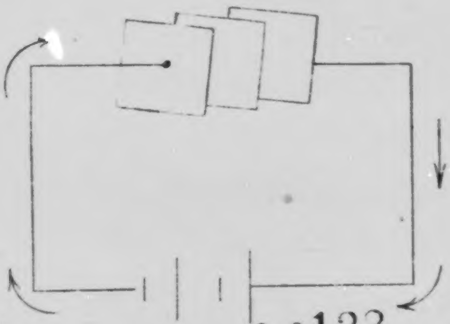
YOU NOW KNOW WHAT A CAPACITOR AND ITS SYMBOL LOOKS LIKE, AND THAT IT CAN STORE AN ELECTRICAL CHARGE. LET'S TAKE A LOOK AT HOW CAPACITORS ARE MADE AND HOW THEY ARE ABLE TO STORE AN ELECTRICAL CHARGE.



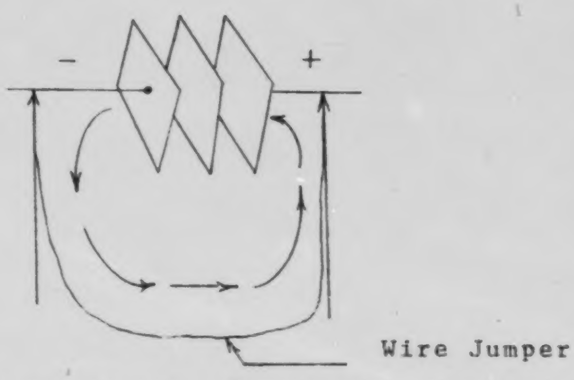
Basic Capacitor

A CAPACITOR IS MADE BY PLACING AN INSULATING MATERIAL BETWEEN TWO METAL PLATES. THE METAL SERVES AS A PLACE TO STORE ELECTRONS. THE INSULATING MATERIAL KEEPS THE ELECTRONS FROM PASSING FROM ONE PLATE TO ANOTHER. THE INSULATING MATERIAL CAN BE AIR, PAPER, MICA, OR OIL.

ANSWER QUESTION #1 AT THE END OF THIS HANDOUT.

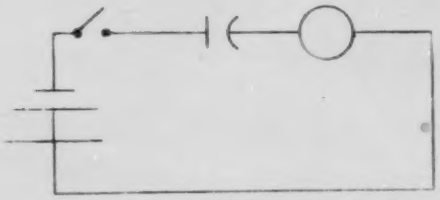


IN THE DIAGRAM ABOVE, A BATTERY IS CONNECTED TO A CAPACITOR. THE BATTERY ATTRACTS ELECTRONS FROM THE RIGHT HAND PLATE TO ITS POSITIVE TERMINAL. IT FORCES ELECTRONS FROM ITS NEGATIVE TERMINAL TO THE LEFT HAND PLATE. REMOVING THE BATTERY LEAVES THE CAPACITOR IN THIS CHARGED STATE. THE CHARGE RESULTS FROM TOO MANY ELECTRONS BEING ON THE LEFT PLATE AND NOT ENOUGH ELECTRONS ON THE RIGHT HAND PLATE. THE CAPACITOR IS CHARGED.



LOOK AT THE DRAWING ABOVE. SHORT CIRCUITING THE CAPACITOR'S TERMINALS WITH A WIRE JUMPER WILL LET THE EXCESS ELECTRONS TRAPPED ON THE LEFT HAND PLATE RETURN TO THE RIGHT HAND PLATE. ELECTRONS WILL CONTINUE TO FLOW UNTIL BOTH PLATES HAVE THE SAME NUMBER OF ELECTRONS. THE CAPACITOR IS DISCHARGED WHEN THIS HAPPENS.

A CAPACITOR WILL BLOCK THE FLOW OF DIRECT CURRENT WHEN IT IS CONNECTED IN A SERIES CIRCUIT. LOOK AT THE CIRCUIT BELOW.



WHEN THE SWITCH IS CLOSED IN THE CIRCUIT ABOVE CURRENT WILL FLOW FOR JUST A MOMENT WHILE THE CAPACITOR IS CHARGING. THIS IS BECAUSE ELECTRONS ARE MOVING FROM THE RIGHT PLATE THROUGH THE LIGHT AND BATTERY TO THE LEFT PLATE. ONCE THE CAPACITOR IS FULLY CHARGED ALL CURRENT FLOW WILL STOP. REMEMBER, THERE IS INSULATION BETWEEN THE PLATES. CURRENT CANNOT FLOW THROUGH THE CAPACITOR. IF CURRENT FLOWS THROUGH A CAPACITOR THEN IT IS DEFECTIVE.

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

IN MOST CASES, AN OHMMETER CAN BE USED TO CHECK A CAPACITOR TO SEE IF IT IS DEFECTIVE. CONNECTING AN OHMMETER TO THE TERMINALS OF A CAPACITOR WILL TELL US ONE OF THE FOLLOWING THINGS.

1. OHMMETER POINTER MOVES TO ZERO OHMS AND THEN SLOWLY RETURNS TO A HIGH RESISTANCE READING.

   THIS TELLS US THE CAPACITOR IS GOOD. THE REASON FOR THIS TYPE OF READING ON THE METER IS THAT THE BATTERY INSIDE THE METER IS CHARGING THE CAPACITOR. WHEN THE CAPACITOR IS FULLY CHARGED IT BEGINS TO BLOCK CURRENT FLOWING THROUGH THE METER. THIS IS WHY THE POINTER RETURNS TO THE HIGH RESISTANCE LEVEL.

ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

2. IF THE POINTER GOES TO ZERO AND STAYS THE CAPACITOR IS DEFECTIVE.

   THIS CONDITION RESULTS FROM A BREAK-DOWN IN THE INSULATION BETWEEN THE PLATES OF THE CAPACITOR. THE CAPACITOR IS SAID TO BE SHORTED.

   ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

3. NO READING. THE CAPACITOR IS DEFECTIVE.

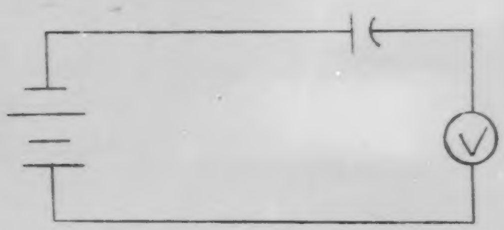
   THIS CONDITION RESULTS WHEN A LEAD BREAKS OR BURNS OFF OF THE PLATES. WHEN THIS HAPPENS ELECTRONS CANNOT GET TO THE PLATES TO CHARGE IT. THE CAPACITOR IS SAID TO BE "OPEN".

   ANSWER QUESTION #5 AT THE END OF THIS HANDOUT.

4. THE OHMMETER POINTER SWINGS TO ZERO AND DROPS BACK TO A LOW RESISTANCE INDICATION. THE CAPACITOR IS DEFECTIVE.

   THIS CONDITION IS A RESULT OF A PARTIAL SHORT AND IS SAID TO BE LEAKING. USUALLY THIS CONDITION IS DUE TO AGING OR MOISTURE.

SOMETIMES A CAPACITOR WILL BREAK DOWN UNDER LOAD. THIS CONDITION CANNOT BE CHECKED WITH AN OHMMETER. A VOLTMETER IS USED FOR THIS CHECK. LOOK AT THE DIAGRAM BELOW.



TO CHECK A CAPACITOR UNDER LOAD CONDITIONS, CONNECT IT IN SERIES WITH A VOLTMETER AT ITS RATED VOLTAGE. YOU SHOULD GET ONE OF THE FOLLOWING VOLTMETER READINGS.

1. NO READING. THE CAPACITOR OPENS UNDER LOAD.

   ANSWER QUESTION #6 AT THE END OF THIS HANDOUT.

2. IF THE VOLTMETER INDICATES FULL VOLTAGE, THE CAPACITOR SHORTS OUT UNDER LOAD CONDITIONS.

   ANSWER QUESTION #7 AT THE END OF THIS HANDOUT.

3. IF THE VOLTMETER POINTER SWINGS TO FULL VOLTAGE AND THEN DROPS BACK TO NEARLY ZERO, THE CAPACITOR IS WORKING O.K.

   ANSWER QUESTION #8 AT THE END OF THIS HANDOUT.

STUDY QUESTIONS

CAPACITOR OPERATION AND TESTING

1. A CAPACITOR IS FORMED BY SEPARATING TWO METAL PLATES WITH AN ________________ MATERIAL.

2. IF CURRENT WILL FLOW THROUGH A CAPACITOR IT IS ______________________.

3. YOU CONNECT YOUR OHMMETER TO A CAPACITOR AND THE POINTER SWINGS TO ZERO AND RETURNS TO SHOW A HIGH RESISTANCE. THIS TELLS YOU THAT THE CAPACITOR IS (GOOD/BAD) __________.

4. IN CHECKING A CAPACITOR, YOUR OHMMETER SHOWS ZERO RESISTANCE. THIS TELLS YOU THAT THE CAPACITOR IS ____________________.

5. WHAT READING WILL YOU GET IF YOU CHECK A CAPACITOR THAT IS OPEN?

6. IF A CAPACITOR OPENS UP UNDER LOAD, THE VOLTMETER READING WILL BE ______________________.

7. IF A CAPACITOR SHORTS OUT UNDER LOAD, THE VOLTMETER WILL READ ______________ VOLTAGE.

8. IF THE CAPACITOR IS WORKING O.K. UNDER LOAD, THE VOLTMETER WILL SWING TO ____________________ VOLTAGE AND THEN DROP BACK TO NEARLY ______________.

EXPERIMENT #2
TESTING CAPACITORS

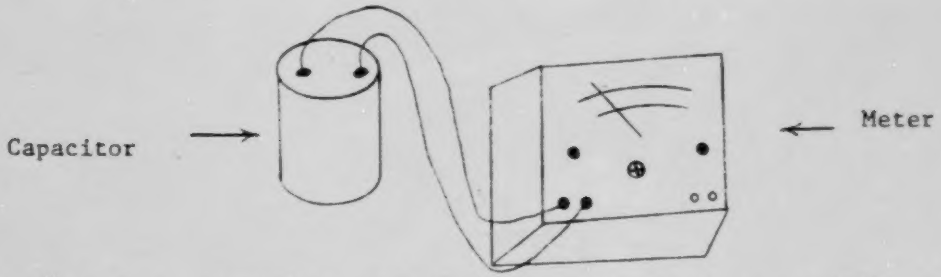
UNIT 03: CAPACITORS, PART 1

REQUIRED MATERIALS:

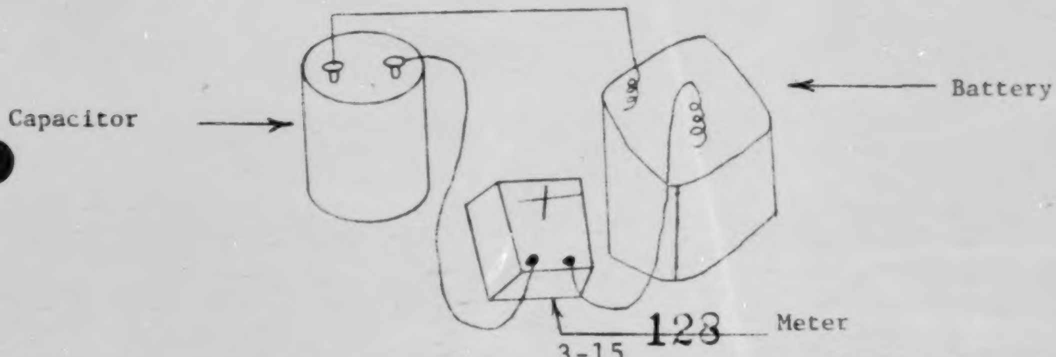
10 - CAPACITORS, ASSORTMENT (GOOD AND BAD)
1 - VOM
1 - BATTERY, 6 VOLT
1 - WIRE LEAD

PROCEDURE:

1. GET ALL THE MATERIAL AND A PLACE TO WORK.
2. CHECK THE CAPACITORS USING THE OHMMETER TO DETERMINE IF THEY ARE EFFECTIVE. SEE ILLUSTRATION BELOW.



3. USE THE VOLTMETER METHOD AND CHECK EACH CAPACITOR AGAIN. SEE ILLUSTRATION BELOW.



STUDENT EXAMINATION #1

UNIT 03: CAPACITORS, PART 1

1. DRAW THE SYMBOL FOR A CAPACITOR.
2. THE VOLTAGE RATING OF A CAPACITOR IS SHOWN AS WVDC. WHAT DOES THIS MEAN?
3. WHAT IS THE BASIC UNIT OF CAPACITANCE?
4. IF YOU HAVE TO REPLACE A CAPACITOR, YOU WOULD REPLACE IT WITH ONE HAVING THE SAME ______________ RATING AND ______________ RATING.
5. WHEN SEVERAL CAPACITORS ARE CONNECTED TOGETHER AS A UNIT THEY ARE CALLED A CAPACITOR ____________________.
6. RESISTORS HAVE RESISTANCE AND POWER RATINGS. CAPACITORS HAVE ____________________ AND ________________ RATINGS.
7. WHAT DOES A CAPACITOR DO?
8. IF CURRENT WILL FLOW THROUGH A CAPACITOR IT IS __________.
9. IN CHECKING A CAPACITOR WITH AN OHMMETER, YOU GET A ZERO OHMS READING. THE CAPACITOR IS (OPEN/SHORTED/GOOD).
10. IN CHECKING A CAPACITOR WITH AN OHMMETER, YOU GET A FULL SCALE READING WHICH THEN RETURNS TO A HIGH RESISTANCE READING. THE CAPACITOR IS (OPEN/SHORTED/GOOD).
11. A CAPACITOR WHICH OPENS UNDER LOAD MUST BE CHECKED WITH A ____________________.

STUDENT COMPETENCY SHEET #1

Unit 03: Capacitors, Part II

Competency Statement: Explains uses of capacitors.

Performance Ojbective:

Action: You will answer questions about how capacitors are used.

Conditions: You have 15 minutes to do this. You may not use references.

Standard: All your answers must be correct.

Learning Activities:

1. Get Student Handout #1, "Capacitors: Charge and Discharge time," from the instructor. Read it. Answer the questions at the end of the handout.
2. Get Experiment #1, "Capacitor Charge and Discharge Time," from the instructor. Complete all steps in the experiment.
3. Get Student Handout #2, "Capacitors: Function or Use," from the instructor. Read it. Answer the questions at the end of the handout.
4. Tell your instructor when you are ready for the examination. Complete the examination.

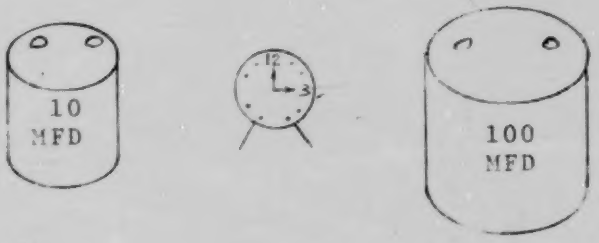
STUDENT HANDOUT #1

CAPACITORS: CHARGE AND DISCHARGE TIME

Unit 03: Capacitors, Part II

Capacitors can be used as timing devices. In your first experiment we learned how to charge a capacitor with a battery. Remember it only took a short time to charge it. How long was that time? Any capacitor requires a certain amount of time to become fully charged. The exact amount of time depends on two things.

First, the number of electrons the capacitor is capable of holding on its plates. This is determined by its capacitance. A capacitor having a large capacitance will hold more electrons than a small capacitor. It takes more time to charge a large capacitor than it does to charge a small one.

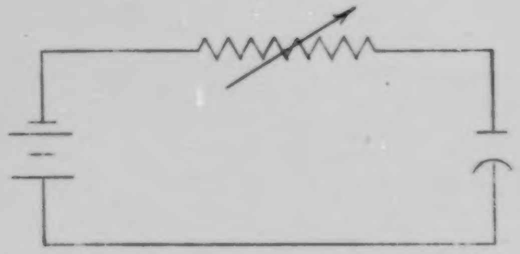


It takes more time to charge a large capacitor

Answer question #1 at the end of this handout.

Second, resistance affects the charging time of a capacitor. To charge a capacitor electrons must be forced to flow from one plate to the other. The speed at which they flow will

AFFECT CHARGING TIME. RESISTANCE OPPOSES ELECTRON MOVEMENT AND CAN THEREFORE BE USED TO CONTROL THE CHARGING TIME OF A CAPACITOR.



THE CIRCUIT ABOVE USES A VARIABLE RESISTOR TO CONTROL THE CHARGING TIME OF THE CAPACITOR. IF THE RESISTANCE IS INCREASED IT WILL TAKE LONGER TO CHARGE THE CAPACITOR. IF IT IS DECREASED IT WILL TAKE LESS TIME TO CHARGE THE CAPACITOR.

ANSWER QUESTION #2 AT THE END OF THIS HANDOUT.

THE DISCHARGE TIME FOR A CAPACITOR IS ALWAYS THE SAME AS THE CHARGING TIME. THIS IS BECAUSE THE SAME NUMBER OF ELECTRONS MUST ALSO MOVE THROUGH THE SAME AMOUNT OF RESISTANCE DURING DISCHARGE AS DURING CHARGING.

ANSWER QUESTION #3 AT THE END OF THIS HANDOUT.

MOST ELECTRONIC TIMING CIRCUITS USE CAPACITORS AND RESISTORS AS A TIMING DEVICE. THEIR ADVANTAGE IS THAT THEY HAVE NO MOVING PARTS AND REQUIRE VERY LITTLE MAINTENANCE.

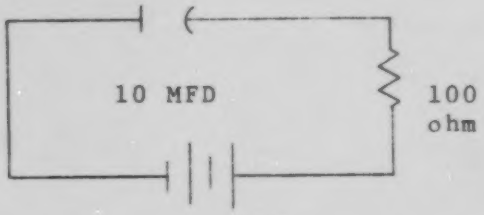
ANSWER QUESTION #4 AT THE END OF THIS HANDOUT.

STUDY QUESTIONS
STUDENT HANDOUT #1

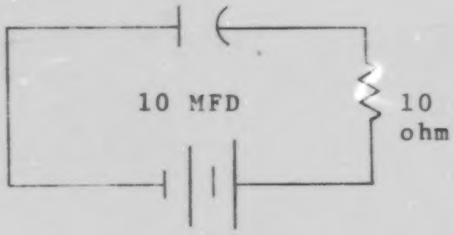
UNIT 03: CAPACITORS, PART II

1. WHICH WILL REQUIRE MORE TIME TO BECOME FULLY CHARGED, A 10 MICROFARAD CAPACITOR OR A 100 MICROFARAD CAPACITOR?

2. WHICH CAPACITOR WILL REQUIRE MORE TIME TO CHARGE, CIRCUIT A OR CIRCUIT B?



A.



B.

3. A CERTAIN CAPACITOR REQUIRES 5 SECONDS TO BECOME FULLY CHARGED. HOW LONG WILL IT TAKE TO DISCHARGE IT UNDER THE SAME CONDITIONS?

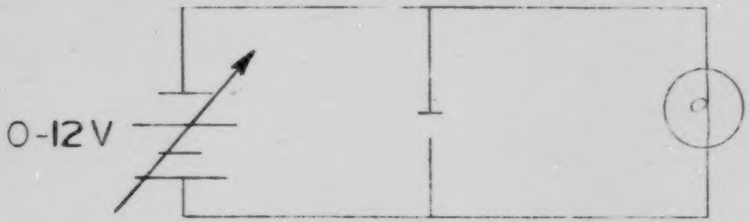
4. COULD CAPACITORS AND RESISTORS BE USED AS TIMING DEVICES?
YES NO

STUDENT HANDOUT #2

CAPACITORS: FUNCTION OR USE

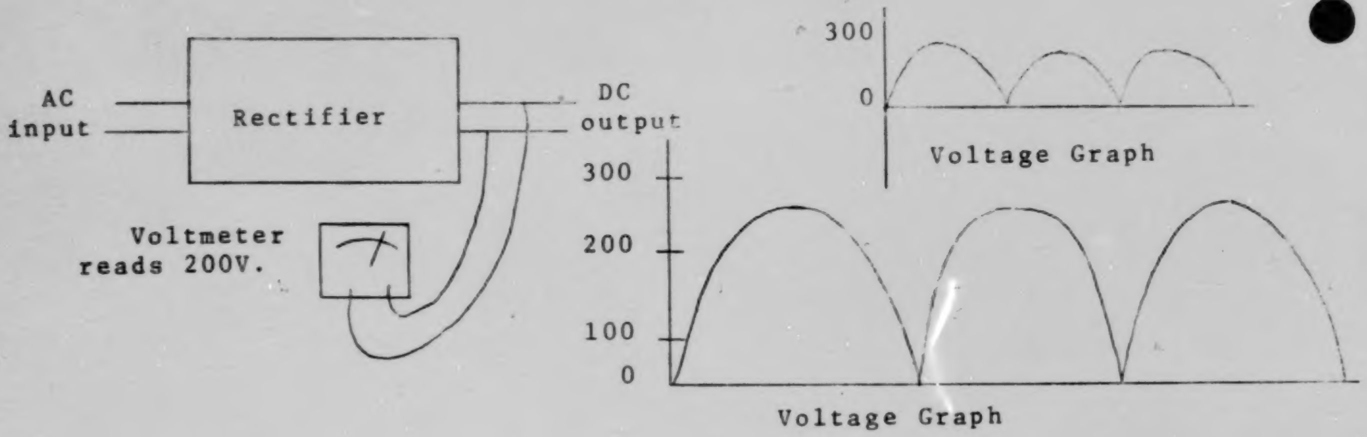
UNIT 03: CAPACITORS, PART II

CAPACITORS HAVE MANY USES. AS A MINING ELECTRICIAN YOU MAY KNOW THAT ONE USE FOR A CAPACITOR IS TO FILTER OR SMOOTH OUT THE RIPPLE IN A DC RECTIFIER. HOW DOES IT DO THIS? REMEMBER THAT A CAPACITOR CAN ONLY CHARGE TO A VOLTAGE EQUAL TO THE POWER SOURCE THAT CHARGES IT.

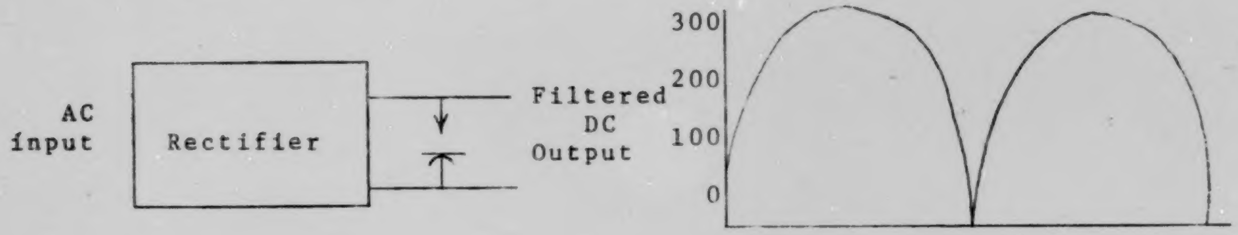


A VARIABLE POWER SUPPLY IS USED IN THE CIRCUIT ABOVE. WHEN SET TO MAXIMUM THE CAPACITOR CHARGES TO 12 VOLTS. THE LAMP BURNS. WHAT HAPPENS IF THE VOLTAGE IS REDUCED TO 6 VOLTS?

IF THE VOLTAGE IS SUDDENLY REDUCED TO 6 VOLTS THE CAPACITOR GIVES UP PART OF ITS CHARGE UNTIL IT AGAIN EQUALS THE SOURCE VOLTAGE. IN DOING THIS THE CAPACITOR HELPS TO KEEP THE CIRCUIT VOLTAGE AT 12 VOLTS FOR A BRIEF INSTANT AFTER THE SOURCE VOLTAGE HAS DROPPED. THIS IS WHY A CAPACITOR CAN BE USED TO INCREASE THE OUTPUT OF A DC POWER SUPPLY.


AC input
Rectifier
DC output
Voltmeter reads 200V.
300
0
Voltage Graph
300
200
100
0
Voltage Graph

THE DC OUTPUT OF THE RECTIFIER ABOVE IS SHOWN BY THE GRAPH. THE VOLTAGE INCREASES FROM ZERO TO A MAXIMUM. IT THEN DECREASES TO ZERO AGAIN. THE AVERAGE VOLTAGE OUTPUT FOR THIS RECTIFIER WOULD ONLY BE ABOUT 200 VOLTS.

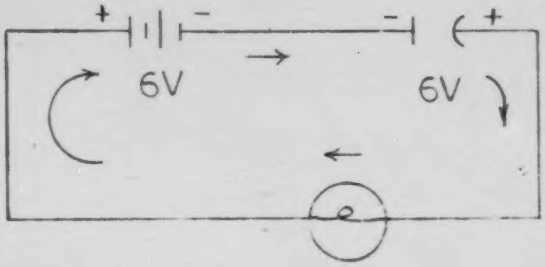

AC input
Rectifier
Filtered DC Output
300
200
100
0

BY CONNECTING A CAPACITOR ACROSS THE OUTPUT TERMINALS OF THE RECTIFIER THE VOLTAGE IS INCREASED. LOOK AT THE GRAPH AT THE RIGHT ABOVE. WHY DOES THIS HAPPEN?

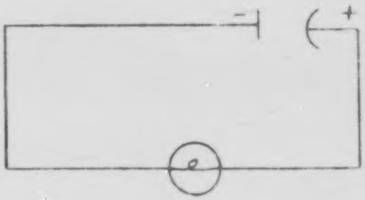
THE OUTPUT VOLTAGE INCREASES BECAUSE THE CAPACITOR IS CHARGED TO 300 VOLTS EACH TIME THE VOLTAGE REACHES MAXIMUM. WHEN THE VOLTAGE BEGINS TO DECREASE THE CAPACITOR GIVES UP ITS CHARGE. THIS HELPS TO KEEP THE VOLTAGE HIGHER. BY THE TIME

THE CAPACITOR DISCHARGES THE VOLTAGE HAS ALREADY STARTED TO INCREASE ON ITS NEXT PULSE. THIS CHARGES THE CAPACITOR AGAIN.

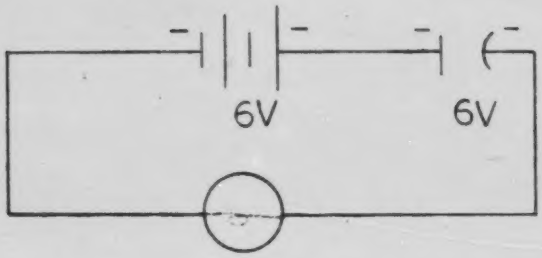
TO UNDERSTAND HOW A CAPACITOR WILL ACT IN AN AC CIRCUIT, FIRST LET'S SEE WHAT HAPPENS IN A DC CIRCUIT WHEN THE POLARITY OF THE BATTERY IS CHANGED.



THE DIAGRAM ABOVE SHOWS THE DIRECTION OF CURRENT FLOW WHILE THE CAPACITOR IS CHARGING. WHEN THE CAPACITOR IS FULLY CHARGED IT WILL BE EQUAL TO THE BATTERY VOLTAGE (6 VOLTS). NOTE THE POLARITY OF THE CHARGE ON THE CAPACITOR.



IF THE BATTERY IS REMOVED THE CAPACITOR WILL REMAIN CHARGED AT 6 VOLTS. NOW LET'S PUT THE BATTERY BACK, BUT IN THE OPPOSITE POLARITY.



WHEN THE BATTERY IS REVERSED, THE CAPACITOR VOLTAGE AND THE BATTERY VOLTAGE WILL ADD TOGETHER. THE LIGHT NOW HAS A TOTAL OF 12 VOLTS CONNECTED TO IT. THE CAPACITOR WILL DISCHARGE AND CHARGE BACK UP IN THE OPPOSITE DIRECTION. CHANGING THE POLARITY OF THE BATTERY AGAIN WILL ALSO PRODUCE 12 VOLTS.

ALTERNATING CURRENT CHANGES ITS DIRECTION 120 TIMES EACH SECOND. IF A CAPACITOR IS CONNECTED IN SERIES WITH AC, IT WILL CONTINUALLY CHARGE AND DISCHARGE. THIS WOULD RESULT IN AN INCREASE IN AC VOLTAGE.

SUMMARY:

THERE ARE MANY USES FOR A CAPACITOR. THE MOST IMPORTANT THING FOR YOU TO REMEMBER ABOUT THEM IS:

1. THEY WILL STORE ELECTRICAL ENERGY.
2. THEY WILL BLOCK DC.
3. THEY ARE CHECKED WITH AN OHMMETER.
4. THEY CAN FILTER OR SMOOTH OUT THE RIPPLE OF A POWER SUPPLY.

5. THEY CAN BE USED TO INCREASE VOLTAGE.

6. THEY CAN BE USED FOR DIMMING PURPOSES.

7. CAPACITORS CAN BE DANGEROUS. SINCE THEY STORE ELECTRICAL CHARGES THEY ARE POTENTIAL SHOCK HAZARDS. NEVER LEAVE A CAPACITOR LYING AROUND IN A CHARGED STATE. NEVER SHORT A CAPACITOR WITH A SCREWDRIVER. SHORTING A LARGE CAPACITOR WOULD BE LIKE SHORT CIRCUITING THE TERMINALS OF A LARGE BATTERY. SERIOUS BURNS OR ELECTRICAL SHOCK MAY RESULT. WHEN DISCHARGING A CAPACITOR, USE A RESISTOR THAT WILL CARRY THE DISCHARGE CURRENT.

STUDY QUESTIONS

Unit 03: Capacitors, Part II

1. Can a capacitor be used to increase the output of a rectifier?   Yes   No

2. How does the capacitor help to increase the output voltage of a DC power supply?

3. How can a capacitor be hazardous?

4. How should a capacitor be discharged?

5. Why are capacitors used on AC motors?

EXPERIMENT #1

CAPACITOR CHARGE AND DISCHARGE TIME

UNIT 03: CAPACITORS, PART II

REQUIRED MATERIALS:

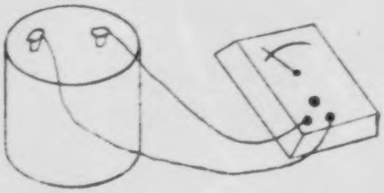
1 - CAPACITOR, 10 MFD (APPROXIMATE)
1 - CAPACITOR, 100 MFD (APPROXIMATE)
1 - RESISTOR, 100 K OHM (APPROXIMATE)
1 - RESISTOR, 1 M-OHM (APPROXIMATE)
1 - BATTERY 6 VOLT
1 - METER, VOM
1 - WIRE LEADS
1 - WRIST WATCH WITH SECOND HAND

PROCEDURE:

1. GET ALL THE MATERIAL AND A PLACE TO WORK.

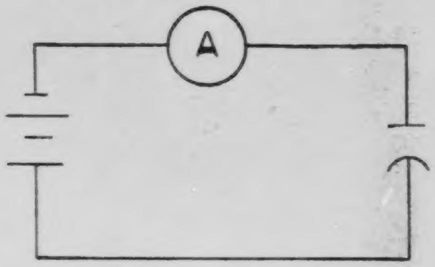
2. SET YOUR METER TO MEASURE RESISTANCE ON THE 10K SCALE.

3. USE THE OHMMETER TO CHARGE BOTH CAPACITORS. RECORD THE CHARGING TIME. SEE DIAGRAM BELOW.

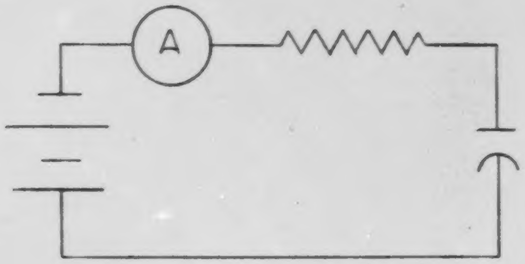


4. DISCHARGE THE CAPACITORS USING A WIRE LEAD.

5. SET YOUR METER TO MEASURE CURRENT AND USE THE BATTERY TO CHARGE THE CAPACITORS. SEE DIAGRAM BELOW. THE CAPACITOR WILL BE FULLY CHARGED WHEN THE POINTER OF THE METER STOPS MOVING.



6. PLACE THE SMALLEST RESISTOR IN SERIES WITH THE CAPACITOR AND RECORD THE CHARGING TIME. SEE DIAGRAM BELOW.



7. PLACE THE LARGEST RESISTOR IN SERIES WITH THE CAPACITOR AND RECORD THE CHARGING TIME.

8. COMPARE THE CHARGING TIMES FOR EACH STEP OF THIS EXPERIMENT.

STUDENT EXAMINATION #1

UNIT 03: CAPACITORS, PART II

1. WHICH CAPACITOR WILL REQUIRE THE GREATEST AMOUNT OF TIME TO BECOME CHARGED? CIRCLE THE CORRECT LETTER.

   A. 10 MFD
   B. 30 MFD
   C. 50 MFD

2. THE RESISTOR USED TO CONTROL THE CHARGING TIME OF A CAPACITOR MUST BE CONNECTED IN (SERIES/PARALLEL) WITH THE CAPACITOR.

3. THE CHARGING TIME OF A CAPACITOR DEPENDS UPON RESISTANCE AND ______________________________.

4. IF THE RESISTANCE USED TO CONTROL THE CHARGING TIME OF A CAPACITOR IS INCREASED, THE CHARGING TIME WILL (DECREASE/INCREASE).

5. A CAPACITOR SHOULD BE DISCHARGED BY SHORTING ITS TERMINALS WITH A SCREWDRIVER. YES NO

6. WHY IS IT NECESSARY TO DISCHARGE A CAPACITOR BEFORE TESTING IT WITH AN OHMMETER?

7. WHAT IS ONE OF THE BIGGEST HAZARDS IN WORKING WITH CAPACITORS?

STUDENT COMPETENCY SHEET #1

UNIT: 04 INDUCTORS, PART I

COMPETENCY STATEMENT: EXPLAINS BASIC PRINCIPLES OF CURRENT-CARRYING CONDUCTORS

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ON BASIC ELECTRICAL PRINCIPLES. THESE QUESTIONS WILL BE ABOUT CURRENT-CARRYING CONDUCTORS.

CONDITIONS: YOU HAVE 20 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1,"A REVIEW OF BASIC PRINCIPLES," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.

2. IF YOUR INSTRUCTOR TELLS YOU, GO TO A TALK. THE TALK IS CALLED "DYNAMIC ELECTRICITY."

3. TELL YOUR INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
A REVIEW OF BASIC PRINCIPLES

UNIT: 04 INDUCTORS, PART I

BEFORE WE TALK ABOUT INDUCTORS, LET'S REVIEW SOME BASIC PRINCIPLES THAT YOU HAVE ALREADY LEARNED.

1. CURRENT-CARRYING CONDUCTOR:

WHEN CURRENT PASSES THROUGH A CONDUCTOR, A MAGNETIC FIELD IS ALWAYS PRODUCED. SUPPOSE THAT FIGURE 1 BELOW IS A SIMPLE CONDUCTOR. YOU ARE LOOKING RIGHT AT IT. IMAGINE THAT THERE IS CURRENT FLOWING. THE CIRCULAR LINES WITH THE ARROWS SHOW THE MAGNETIC FIELD.

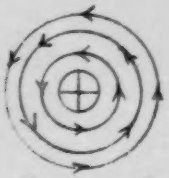


FIGURE 1
CURRENT-CARRYING CONDUCTOR

IF THERE IS MORE CURRENT, THE MAGNETIC FIELD WILL SPREAD OUT MUCH FURTHER FROM THE CONDUCTOR. IN OTHER WORDS, THE STRENGTH OF THE MAGNETIC FIELD AROUND A CONDUCTOR IS PROPORTIONAL TO THE AMOUNT OF CURRENT GOING THROUGH THE CONDUCTORS.

ANSWER QUESTION #1 AT THE END OF THE HANDOUT.

2. PARALLEL CONDUCTORS

WHEN CONDUCTORS ARE SIDE BY SIDE, THE MAGNETIC FIELD PRODUCED BY ONE WILL ALSO INDUCE A CURRENT IN THE ONE NEXT TO IT. LOOK AT FIGURE 2.

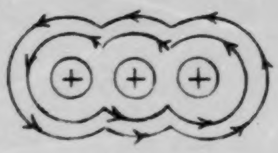


FIGURE 2
PARALLEL CONDUCTORS

LET'S IMAGINE THAT FIGURE 1 IS A THREE-TURN COIL AND THAT WE HAVE SLICED THROUGH ITS MIDDLE. NOTICE THAT THE MAGNETIC FIELD IS ALL AROUND ALL OF THE CONDUCTORS, NOT JUST EACH ONE BY ITSELF. A STRANGE THING HAPPENS NOW. ALL THE MAGNETISM ADDS TOGETHER AND MAKES A MAGNETIC FIELD THREE TIMES AS STRONG AS THE MAGNETIC FIELD OF FIGURE 1. REMEMBER, WE HAVE NOT CHANGED THE AMOUNT OF CURRENT, JUST THE NUMBER OF CONDUCTORS. THIS IS THE PRINCIPLE ON WHICH COILS ARE BASED, THAT IS, THE AMOUNT OF MAGNETISM PRODUCED IN A COIL IS PROPORTIONAL TO THE NUMBERS OF TURNS OF WIRE IN THE COIL AND THE CURRENT PASSING THROUGH IT.

HEY, WAIT A MINUTE. YOU SAID THAT WHEN CONDUCTORS ARE SIDE BY SIDE, THE MAGNETIC FIELD PRODUCED BY ONE CONDUCTOR INDUCES A CURRENT IN THE ONE NEXT TO IT. WHY DOESN'T THE CURRENT MULTIPLY TOO, JUST LIKE THE MAGNETIC FIELD? GOOD

QUESTION. IT SURE WOULD BE NICE TO GET ALL THAT FREE CURRENT, WOULDN'T IT? IT'S TOO BAD, THOUGH, BECAUSE THE CURRENT THAT ONE CONDUCTOR INDUCES IN THE CONDUCTOR NEXT TO IT ALWAYS GOES IN THE OPPOSITE DIRECTION TO THE CURRENT THAT PRODUCED THE MAGNETISM IN THE FIRST PLACE. WE CALL THIS INDUCTIVE REACTANCE, OR COUNTER ELECTROMOTIVE FORCE. LUCKILY, THERE ARE ABBREVIATIONS FOR THESE. INDUCTIVE REACTANCE IS REPRESENTED BY THE LETTERS XL. WHERE "X" IS REACTANCE AND "L" IS INDUCTANCE. COUNTER ELECTROMOTIVE FORCE IS CEMF.

ANSWER QUESTION #2 AT THE END OF THE HANDOUT.

CAN YOU THINK OF ANY CONVENTIONAL COMPONENTS OTHER THAN COILS THAT WOULD CREATE THIS SITUATION? WHAT ABOUT THE FIELD OF MOTORS AND GENERATORS?

3. INDUCTORS

OK, WE'VE TALKED ABOUT COILS AND MOTOR FIELDS AND INDUCTIVE REACTANCE (XL) AND COUNTER ELECTROMOTIVE FORCE (CEMF). NOW, WHAT IS AN INDUCTOR? ACTUALLY, AN INDUCTOR IS A COIL, BUT IT IS A SPECIAL KIND OF COIL. THE CONVENTIONAL OR USUAL CONTACTOR, SUCH AS THE ONE USED ON A 10SC SHUTTLE CAR, HAS AN OPERATING COIL WITH MANY TURNS OF FINE WIRE WRAPPED ON ITS CORE. THE MAIN PURPOSE HERE IS TO HAVE ENOUGH MAGNETIC STRENGTH TO CLOSE THE CONTACTOR AND COMPLETE A CIRCUIT. INDUCTIVE REACTANCE OCCURS BUT IS NOT A FACTOR; IT JUST HAPPENS. AN INDUCTOR, ON THE OTHER HAND, IS A COIL WOUND WITH A CERTAIN NUMBER OF TURNS OF WIRE TO PRODUCE A DEFINITE AMOUNT OF INDUCTANCE.

4. Collapsing Magnetic Fields

You've heard the expression "whatever goes up must come down." The same is true with magnetic fields. If a magnetic field goes in one direction when current is passed through a conductor, that same magnetic field has to move in the opposite direction when the current stops. We refer to this as magnetic field collapse.

Answer question #4 at the end of the handout.

When the magnetic field moves away from the conductor as current is applied, it induces a current opposite to that which produces it. Look at Figures 3 and 4.

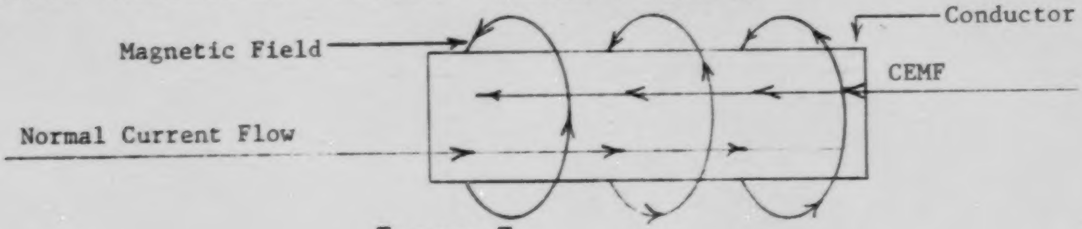

Conductor
Magnetic Field
CEMF
Normal Current Flow

Figure 3

Current Passing Through a Conductor

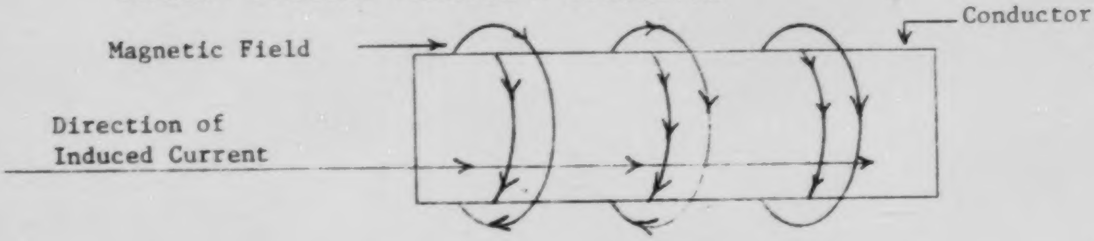

Conductor
Magnetic Field
Direction of
Induced Current

Figure 4

Collapsing Magnetic Field and Resultant Current

COMPARE THE DIRECTION SHOWN BY THE ARROWS OF THE MAGNETIC FIELD IN FIGURES 3 AND 4. NOW COMPARE THE DIRECTION OF CURRENT FLOW IN BOTH FIGURES. YOU WILL SEE THAT THE ORIGINAL DIRECTION OF CURRENT FLOW DOES NOT CHANGE.

5. THINGS TO THINK ABOUT

A. WHENEVER CURRENT TO A MOTOR STOPS, THE MAGNETIC FIELD COLLAPSES IN THE MOTOR FIELDS.

B. THE COLLAPSING MAGNETIC FIELD INDUCES A CURRENT IN THE MOTOR FIELDS IN THE SAME DIRECTION AS THE FIRST CURRENT.

C. COILS STORE ENERGY IN THE FORM OF A MAGNETIC FIELD. THIS ENERGY IS WASTED IN THE FORM OF HEAT LOSS.

D. THROUGH SOLID-STATE CIRCUITRY, WE'RE GOING TO CAPTURE THIS WASTED ENERGY AND PUT IT TO WORK FOR US.

6. SUMMARY

KEEP THESE BASIC PRINCIPLES IN MIND.

A. A MAGNETIC FIELD OCCURS AROUND A CONDUCTOR WHENEVER CURRENT PASSES THROUGH IT.

B. AS THE MAGNETIC FIELD GETS LARGER, IT INDUCES A CURRENT OPPOSITE TO THAT WHICH PRODUCED IT.

C. WHEN THE SUPPLIED CURRENT STOPS, THE MAGNETIC FIELD COLLAPSES.

D. THIS COLLAPSE INDUCES A CURRENT OF ITS OWN.

E. THE CURRENT WHICH IS INDUCED BECAUSE OF THE MAGNETIC COLLAPSE WILL FLOW IN THE SAME DIRECTION AS THE SUPPLIED CURRENT DID.

F. AN INDUCTOR IS A COIL WOUND WITH A SPECIFIC NUMBER OF TURNS TO PRODUCE A CERTAIN AMOUNT OF INDUCTANCE.

7. IN CONVENTIONAL MOTORS, INDUCTIVE REACTANCE TURNS TO HEAT.

QUESTIONS

1. THE STRENGTH OF THE MAGNETIC FIELD AROUND A CONDUCTOR IS ____________________ TO THE AMOUNT OF CURRENT GOING THROUGH THE CONDUCTOR.

2. WHAT ARE THF LETTER SYMBOLS USED FOR INDUCTIVE REACTANCE AND COUNTER ELECTROMOTIVE FORCE?

   ____________________ ____________________

3. AN INDUCTOR IS A COIL WOUND WITH A CERTAIN NUMBER OF TURNS OF WIRE TO PRODUCE WHAT?

4. EXPLAIN MAGNETIC FIELD COLLAPSE.

STUDENT EXAMINATION #1

A REVIEW OF BASIC PRINCIPLES

UNIT: 04 INDUCTORS, PART I

1. CURRENT PASSING THROUGH A COIL CREATES A(N) ____________ ______________.

2. EXPLAIN WHAT HAPPENS IN A COIL WHEN THE CURRENT SUDDENLY STOPS FLOWING.

3. IN A MOTOR FIELD COIL, WHICH DIRECTION DOES THE INDUCED CURRENT FLOW DURING COLLAPSE?

4. THE MORE TURNS THAT THERE ARE ON A COIL, THE MORE ____________ IT WILL PRODUCE WHEN CURRENT TRAVELS THROUGH IT.

5. A COIL THAT IS WOUND TO PRODUCE A SPECIFIC AMOUNT OF INDUCTANCE IS CALLED A(N) ____________________.

6. WHAT LETTER COMBINATION IS USED TO INDICATE INDUCTIVE REACTANCE? __________________

7. NAME AT LEAST TWO CONVENTIONAL ELECTRICAL DEVICES THAT OPERATE ON THE PRINCIPLES OF INDUCTANCE.

STUDENT COMPETENCY SHEET #2

UNIT: 04 INDUCTORS, PART II

COMPETENCY STATEMENT: EXPLAINS HOW INDUCTORS ARE USED AND IDENTIFIES AND DRAWS ITS SYMBOL

PERFORMANCE OBJECTIVE:

ACTION:	YOU WILL IDENTIFY AN INDUCTOR BY WHAT IT LOOKS LIKE, DRAW ITS SYMBOL, AND TELL HOW IT IS USED.
CONDITIONS:	YOU HAVE 15 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.
STANDARD:	ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "FUNCTION, IDENTIFICATION, AND SYMBOL OF INDUCTORS," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.

2. TELL YOUR INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

FUNCTION, IDENTIFICATION, AND SYMBOL OF INDUCTORS

UNIT: 04 INDUCTORS, PART II

YOU LEARNED IN THE LAST HANDOUT THAT AN INDUCTOR IS WOUND TO GIVE A CERTAIN AMOUNT OF INDUCTANCE. IT IS USED TO PROVIDE A DEFINITE AMOUNT OF INDUCTANCE IN A CIRCUIT TO CAUSE IT TO ACT IN A CERTAIN WAY.

ANSWER QUESTION #1 AT THE END OF THE HANDOUT.

IN CONVENTIONAL CIRCUITS, RESISTORS ARE USED TO REDUCE CURRENT TO SAFE VALUES, SUCH AS THE SERIES STARTING RESISTORS USED ON MINE EQUIPMENT. THERE IS NOTHING MYSTERIOUS ABOUT INDUCTORS. IT IS JUST ANOTHER ELECTRICAL COMPONENT IN A CIRCUIT. THE ONLY DIFFERENCE IS THAT NOW OUR CIRCUITS ARE BECOMING A LITTLE MORE COMPLICATED.

SIZE AS WELL AS SHAPE IS IMPORTANT FOR IDENTIFICATION OF INDUCTORS. IN THE CIRCUITS THAT YOU WILL SEE, THE INDUCTORS WILL BE MUCH SMALLER THAN THE CONVENTIONAL COILS THAT YOU ARE FAMILIAR WITH. ALSO A CONVENTIONAL COIL WILL HAVE CONNECTIONS FOR SCREWS. THE INDUCTOR WILL BE SOLDERED INTO A CIRCUIT.

ANSWER QUESTION #2 AT THE END OF THE HANDOUT.

SYMBOL:

THE SYMBOLS FOR INDUCTORS ARE BELOW:

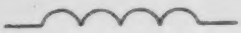


FIGURE 1-A
AIR CORE

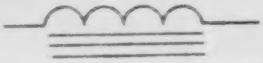


FIGURE 1-B
IRON CORE

NOTICE THAT ONE HAS AN IRON CORE BUT THE OTHER DOES NOT. CAN YOU THINK WHY? THINK ABOUT MAGNETISM. YOU WILL REMEMBER THAT THE IRON CORE WILL INCREASE THE MAGNETIC FIELD MANY TIMES AND INDUCTANCE WILL INCREASE.

ANSWER QUESTION #3 AT THE END OF THE HANDOUT.

CIRCUITS:

WHEN INDUCTORS ARE USED IN CIRCUITS WITH OTHER COMPONENTS SUCH AS RESISTORS OR CAPACITORS, WE USE SHORTER NAMES TO DESCRIBE THEM. FOR EXAMPLE:

A. INDUCTOR AND RESISTOR IS CALLED AN RL CIRCUIT
B. INDUCTOR AND CAPACITOR IS CALLED AN LC CIRCUIT.
C. INDUCTOR, RESISTOR, AND CAPACITOR IS CALLED AN RLC CIRCUIT

SPECIFIC PURPOSES:

AN INDUCTOR CAN ACT LIKE OTHER COMPONENTS; IN OTHER WORDS IT CAN BE QUITE AN "IMPERSONATOR" AT TIMES. LISTED BELOW ARE SOME OF THE THINGS IT WILL DO IN A CIRCUIT AND HOW IT WILL ACT.

A. DURING COLLAPSE, AN INDUCTOR CAN ASSIST THE SOURCE VOLTAGE. IT ACTS LIKE A TRANSFORMER.

B. DURING THE BUILDUP PERIOD, OR WHEN CURRENT BEGINS TO PASS THROUGH IT, THE RESULTING MAGNETISM OPPOSES SOURCE VOLTAGE. THE INDUCTOR BECOMES A RESISTANCE.

C. DURING COLLAPSE, AN INDUCTOR CAN DISCHARGE ITS ENERGY AND ACT LIKE A CAPACITOR.

ANSWER QUESTION #4 AT THE END OF THE HANDOUT.

QUESTIONS:

1. HOW IS AN INDUCTOR USED?

2. DESCRIBE THE SIZE OF AN INDUCTOR.

3. DRAW THE SYMBOL FOR AN INDUCTOR.

4. TELL THREE WAYS AN INDUCTOR CAN BE AN "IMPERSONATOR."

STUDENT COMPETENCY SHEET #1

UNIT: 04 INDUCTORS, PART III

COMPETENCY STATEMENT: EXPLAINS OPERATION OF INDUCTORS IN A CIRCUIT

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT INDUCTOR OPERATION.

CONDITIONS: YOU HAVE 15 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "INDUCTOR OPERATION," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.

2. GET EXPERIMENT #1, "INDUCTOR OPERATION," FROM THE INSTRUCTOR. DO ALL THE STEPS OF THE EXPERIMENT.

3. TELL YOUR INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT SHEET #1
INDUCTOR OPERATION

UNIT: 04 INDUCTORS, PART III

TO UNDERSTAND INDUCTOR OPERATION, LET'S FIRST LOOK AT A SIMPLE DC CIRCUIT WITH AN INDUCTOR AND A RESISTOR.

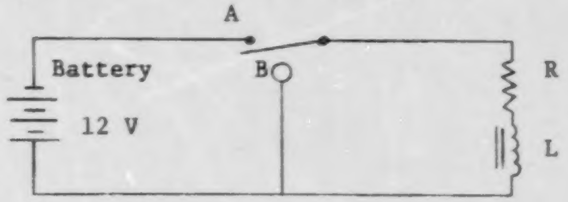


FIGURE 1
R L CIRCUIT

IN FIGURE 1 WE HAVE A BATTERY, A SWITCH, A RESISTOR (R), AND AN INDUCTOR (L).

WHEN WE CLOSE THE SWITCH AT POINT A, (1) A VOLTAGE OF 12 VOLTS APPEARS ACROSS THE COIL, (2) CURRENT DOES NOT REACH MAXIMUM RIGHT AWAY. WHY?

DO YOU REMEMBER INDUCTIVE REACTANCE, (XL)? AN INDUCTOR INDUCES A VOLTAGE IN ITSELF THAT OPPOSES THE VOLTAGE THAT PRODUCED IT. IN AN INDUCTIVE CIRCUIT WE SAY THAT THE VOLTAGE LEADS THE CURRENT. THIS IS JUST ANOTHER WAY OF SAYING THE VOLTAGE IS THERE BEFORE THE CURRENT.

ANSWER QUESTION #1 AT THE END OF THE HANDOUT.

IN A DC CIRCUIT, HOWEVER, AFTER A VERY SHORT TIME, CURRENT WILL REACH ITS GREATEST VALUE. THE MAGNETIC FIELD AROUND THE INDUCTOR WILL GROW LARGER AS LONG AS CURRENT CONTINUES TO REACH TOWARD ITS MAXIMUM. ONCE THIS MAXIMUM CURRENT IS REACHED, THE MAGNETIC FIELD IS COMPLETE AND THE COIL ACTS JUST LIKE A PIECE OF STRAIGHT WIRE. THERE IS NO MORE REACTANCE. REMEMBER, THE MAGNETIC FIELD HAS TO BE MOVING TO PRODUCE A VOLTAGE.

NOW LET'S MOVE THE SWITCH TO POSITION "B". WE HAVE CUT OFF THE BATTERY-SUPPLY CURRENT AND SHORTED ACROSS THE INDUCTOR AND RESISTOR. THE MAGNETIC FIELD OF THE COIL BEGINS TO COLLAPSE. CURRENT IS INDUCED THROUGH THE CIRCUIT IN THE SAME DIRECTION AS THE ORIGINAL CURRENT PRODUCED BY THE BATTERY.

ANSWER QUESTION #2 AT THE END OF THE HANDOUT.

NOW LET'S TAKE A LOOK AT A SIMILAR CIRCUIT. THIS TIME WE WILL TAKE OUT THE BATTERY AND PUT IN AN AC SOURCE.

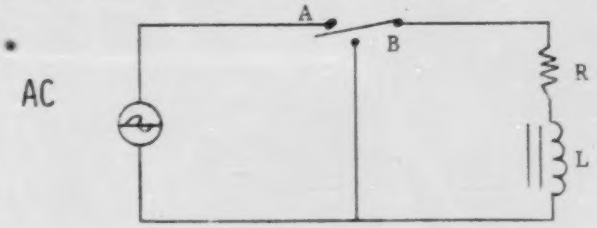


FIGURE 2

AC INDUCTIVE CIRCUIT

IN THE CIRCUIT OF FIGURE 2 ABOVE, WITH THE SWITCH IN POSITION "A," THE CURRENT CHANGES DIRECTION TWICE FOR EACH CYCLE. THIS HAPPENS 120 TIMES A SECOND. THE INDUCTOR UNDER THESE CONDITIONS ACTS AS AN OPPOSITION TO CURRENT FLOW, OR, AS WE SAY FOR AC CIRCUITS, AS AN IMPEDANCE. THE MAGNETIC FIELD AROUND THE INDUCTOR KEEPS BUILDING UP AND COLLAPSING EACH TIME CURRENT CHANGES DIRECTION.

ANSWER QUESTION #3 AT THE END OF THE HANDOUT.

IF WE WERE TO SWITCH TO POINT "B" AT ANY GIVEN TIME, WE REALLY COULDN'T BE SURE WHAT VALUE OF VOLTAGE WOULD APPEAR ACROSS THE INDUCTOR. LOOK AT FIGURE 3.

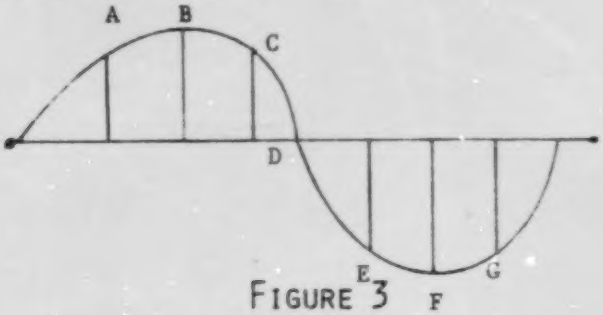


FIGURE 3

CURRENT WAVE FORM

IF WE WERE TO MANUALLY SWITCH AT POINTS "B" OR "F," THE INDUCTOR WOULD HAVE MAXIMUM CURRENT. IF WE HAPPENED TO SWITCH AT POINT "D," CURRENT WOULD BE CHANGING DIRECTION. VOLTAGE ACROSS THE INDUCTOR WOULD BE MAXIMUM AT POINT "D." THIS IS BECAUSE VOLTAGE LEADS CURRENT BY 90 DEGREES IN THE INDUCTIVE CIRCUIT.

INDUCTIVE KICK:

EACH TIME THAT A CURRENT PASSING THROUGH AN INDUCTOR IS CUT OFF, CHANGES DIRECTION, OR IS INTERRUPTED, THE MAGNETIC FIELD COLLAPSES. THE SPEED AT WHICH THIS FIELD COLLAPSES AND THE NUMBER OF TURNS ON THE INDUCTOR TELL US HOW MUCH VOLTAGE THE INDUCTOR WILL INDUCE IN ITS OWN WINDINGS OR TURNS.

ANSWER QUESTION #5 AT THE END OF THE HANDOUT.

THIS IS AN INDUCTIVE KICK. IT'S JUST LIKE GETTING A "KICK" IN THE PANTS; WHEN THIS OCCURS, SOMETHING USUALLY HAPPENS, DOESN'T IT?

THIS INDUCTIVE KICK CAUSES SOMETHING TO HAPPEN, TOO. WE CAN USE THIS HIGHER INDUCED VOLTAGE TO DO WORK FOR US, SUCH AS CHARGE A CAPACITOR, OR FIRE AN SCR INTO CONDUCTION.

ANSWER QUESTION #6 AT THE END OF THE HANDOUT.

SINCE AN INDUCTOR IS A COIL OF WIRE AND IS DESIGNED FOR CURRENT TO FLOW THROUGH IT, THEN IT MUST HAVE RESISTANCE. SINCE IS HAS RESISTANCE, AN OHMMETER CAN BE USED TO DETERMINE IF IT IS DEFECTIVE. (SEE ILLUSTRATION BELOW)

A HIGH RESISTANCE READING TELLS US THAT IT IS A GOOD COIL. A LOW RESISTANCE READING TELLS US THAT IT IS SHORTED OR SHORT-CIRCUITED. NO READING WOULD TELL US THE WINDING IS BURNED INTO OR OPEN-CIRCUITED. ANSWER QUESTION #7 AT THE END OF THE HANDOUT.

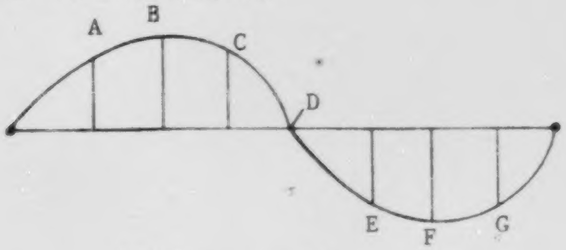
QUESTIONS

1. WHAT HAPPENS IN AN INDUCTIVE CIRCUIT SO THAT WE CAN SAY "VOLTAGE LEADS CURRENT"?

2. WHICH WAY IS CURRENT INDUCED IN A DC CIRCUIT WHEN THE MAGNETIC FIELD COLLAPSES? CIRCLE THE CORRECT LETTER.
   A. SAME DIRECTION AS ORIGINAL CURRENT.
   B. OPPOSITE DIRECTION AS ORIGINAL CURRENT.

3. WHAT DOES IMPEDANCE MEAN IN AN AC CIRCUIT?

4. LOOK AT THE FIGURE BELOW.



AC CURRENT WAVE FORM

   A. WHEN IS VOLTAGE ACROSS THE INDUCTOR THE GREATEST? CIRCLE THE CORRECT ANSWER.

      A B C D E F G

5. WHAT HAPPENS WHEN CURRENT PASSING THROUGH AN INDUCTOR CHANGES DIRECTION?

6. WHICH VOLTAGE IS HIGHER BECAUSE OF INDUCTIVE KICK? CIRCLE THE CORRECT LETTER.

   A. ORIGINAL VOLTAGE.

   B. INDUCED VOLTAGE.

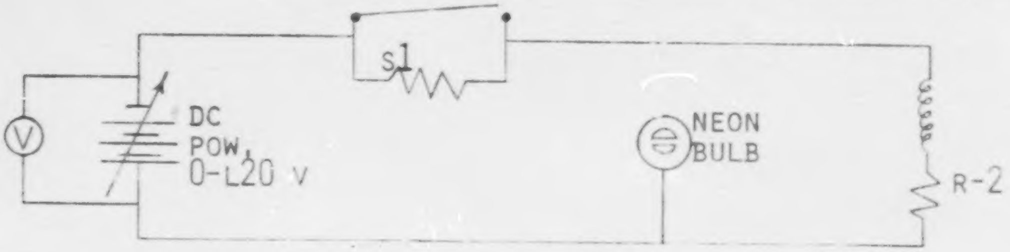
7. HOW DO YOU DETERMINE IF A COIL IS GOOD OR BAD?

EXPERIMENT #1

INDUCTOR OPERATION

UNIT: 04 INDUCTORS, PART III

INSTRUCTIONS: GET THE POWER SUPPLY AND CIRCUIT BOARD FROM THE INSTRUCTOR. THE SCHEMATIC SHOWN BELOW IS FOR YOUR CIRCUIT BOARD. STUDY THE CIRCUIT SCHEMATIC TO SEE IF YOU CAN FIGURE OUT WHAT WILL HAPPEN.



1. CONNECT THE POWER SUPPLY TO THE CIRCUIT BOARD.
2. CONNECT THE VOLTMETER AS SHOWN.
3. WITH THE INSTRUCTOR'S PERMISSION, TURN POWER SUPPLY UNTIL 10 VOLTS APPEAR ON THE VOLTMETER. NOTICE THAT THE BULB WILL NOT LIGHT AT THIS VOLTAGE. THE BULB IS NEON AND ACTS LIKE AN OPEN CIRCUIT AT THIS TIME.
4. CONTINUE TO TURN THE CONTROL KNOB TO THE RIGHT UNTIL THE BULB GLOWS OR UNTIL YOU REACH 90 VOLTS. WATCH THE VOLTMETER.
5. RECORD THE VOLTMETER READING.
6. DECREASE THE VOLTAGE UNTIL 10 VOLTS AGAIN APPEAR ON THE VOLTMETER.

7. CLOSE S2. THIS CONNECTS THE INDUCTOR INTO THE CIRCUIT.

8. OPERATE S1 WHILE LOOKING AT THE BULB. WHAT HAPPENED? WHY?

9. WRITE A BRIEF EXPLANATION IN YOUR OWN WORDS TELLING WHAT YOU THINK IS HAPPENING IN THE CIRCUIT.

10. PUT ALL MATERIALS BACK IN THEIR PROPER PLACE.

STUDENT EXAMINATION #3

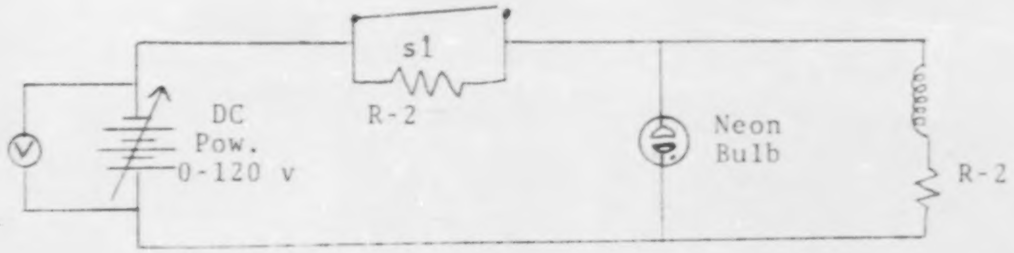
Unit: 04 Inductors, Part III

1. During collapse of the magnetic field across the inductor, the voltage induced is: (Circle the right answer.)
   A. Lower than supply voltage.
   B. Higher than supply voltage.
   C. Same as supply voltage.
   D. None of the above.

2. What causes an inductor to act like a resistance in an AC circuit?

3. In an inductive circuit using AC or DC, explain why the voltage leads the current by 90 degrees.

4.



In the circuit above, if S1 is opened why would the bulb light?

5. Does inductive "Kick" occur in an electric motor?

6. What kind of meter is used to check an inductor coil?

STUDENT COMPETENCY SHEET #1

UNIT: 05 DIODES, PART I

COMPETENCY STATEMENT: IDENTIFIES DIODES AND THEIR SYMBOL AND EXPLAINS FUNCTION.

PERFORMANCE OBJECTIVE:

ACTION:	YOU WILL IDENTIFY A DIODE BY WHAT IT LOOKS LIKE AND ANSWER QUESTIONS ABOUT ITS SYMBOL AND FUNCTION.
CONDITIONS:	YOU HAVE 15 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.
STANDARD:	ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GO TO A DISPLAY TABLE SET UP BY THE INSTRUCTOR. LOOK AT THE DIODES AND THE OTHER COMPONENTS.
2. GET STUDENT HANDOUT #1, "DIODES: IDENTIFICATION AND FUNCTION," FROM THE INSTRUCTOR. READ IT AND THEN ANSWER THE STUDY QUESTIONS.
3. GET EXPERIMENT #1, "TESTING DIODES," FROM THE INSTRUCTOR. COMPLETE ALL STEPS IN THE EXPERIMENT.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

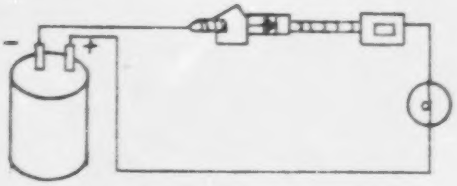
STUDENT HANDOUT #1

DIODES: IDENTIFICATION AND FUNCTION

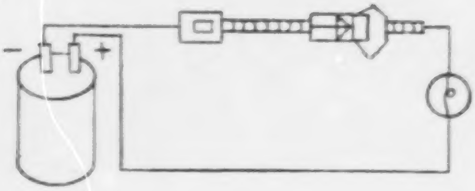
UNIT: 05 DIODES, PART I

A DIODE IS AN ELECTRICAL COMPONENT THAT LETS CURRENT FLOW THROUGH IT IN ONE DIRECTION, BUT BLOCKS CURRENT FLOW IN THE OTHER DIRECTION.

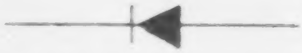
IN CIRCUIT A BELOW THE DIODE WILL ALLOW CURRENT TO FLOW AND THE LAMP BURNS. IN CIRCUIT B BELOW NO CURRENT WILL FLOW. THIS IS BECAUSE THE DIODE HAS BEEN REVERSED AND IS BLOCKING THE CURRENT.



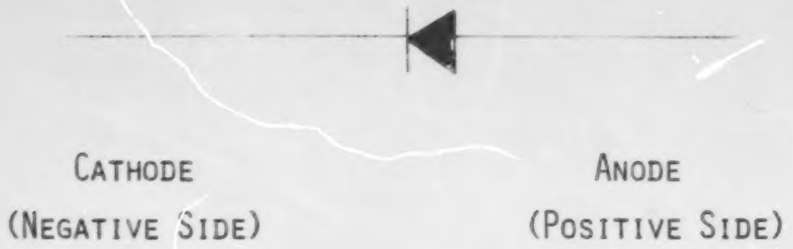
CIRCUIT A



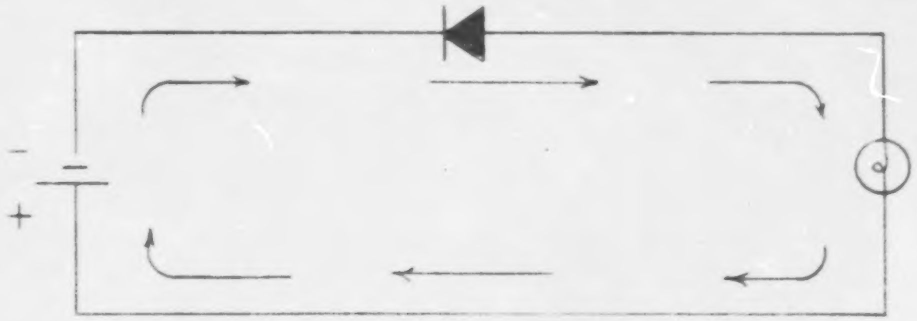
CIRCUIT B

THE SYMBOL FOR A DIODE IS: 

THE TWO CONNECTIONS OF A DIODE ARE CALLED THE CATHODE AND THE ANODE. CURRENT WILL FLOW THROUGH THE DIODE FROM THE CATHODE TO THE ANODE. MANY PEOPLE CALL THE CATHODE THE NEGATIVE SIDE OF THE DIODE AND THE ANODE THE POSITIVE SIDE.

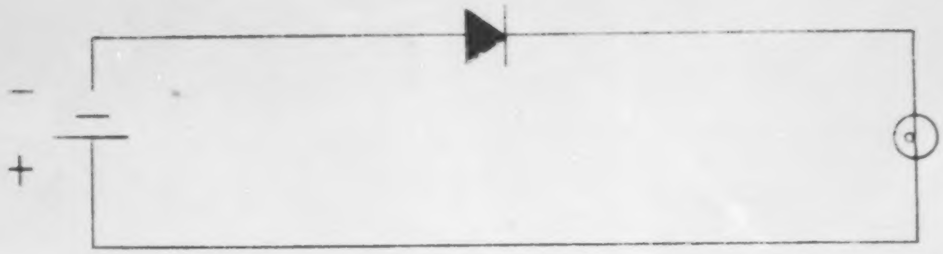


ELECTRICITY FLOWS FROM NEGATIVE TO POSITIVE. IN THE CIRCUIT BELOW CURRENT WILL FLOW IN A CLOCKWISE DIRECTION. THE CATHODE OF THE DIODE IS CONNECTED TO THE NEGATIVE SIDE OF THE SOURCE AND THE ANODE IS CONNECTED TO THE POSITIVE SIDE.

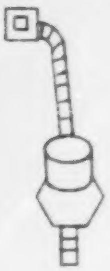


WHEN A DIODE IS CONNECTED THIS WAY IT IS SAID TO BE FORWARD BIASED. FORWARD BIASED MEANS THAT THE DIODE IS CONNECTED SO THE CURRENT WILL FLOW THROUGH IT.

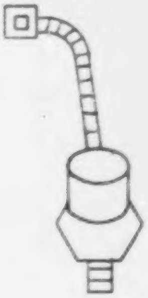
IN THE CIRCUIT BELOW THE CATHODE OF THE DIODE IS CONNECTED TO THE POSITIVE SIDE OF THE SOURCE AND THE ANODE IS CONNECTED TO THE NEGATIVE SIDE. THE DIODE WILL BLOCK THE FLOW OF CURRENT WHEN IT IS CONNECTED THIS WAY, IT IS SAID TO BE REVERSED BIASED. REVERSE BIASED MEANS THAT THE DIODE IS CONNECTED SO THE CURRENT FLOW IN THE CIRCUIT IS BLOCKED.



LARGE DIODES HAVE A STUD-TYPE BASE. THE BASE IS USED TO MOUNT THE DIODE. THE BASE IS ALSO ONE OF THE ELECTRICAL TERMINALS. LOOK AT THE PICTURES BELOW. DIODES CAN HAVE EITHER A CATHODE BASE OR AN ANODE BASE. YOU CAN TELL THE TYPE OF BASE BY LOOKING AT THE SYMBOL.



CATHODE
(NEGATIVE BASE)



ANODE
(POSITIVE BASE)

DIODES ARE RATED BY HOW MUCH CURRENT AND VOLTAGE THEY CAN SAFELY HANDLE. THE FORWARD CURRENT RATING TELLS US HOW MUCH CURRENT A DIODE CAN HANDLE WITHOUT BEING DESTROYED.

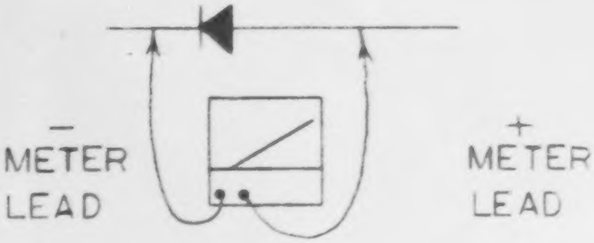
WHEN CURRENT FLOWS THROUGH A DIODE HEAT BUILDS UP. THIS IS BECAUSE THE DIODE HAS SOME RESISTANCE. IF HEAT BUILDS UP BEYOND THE FORWARD CURRENT RATING THE DIODE WILL BE DESTROYED.

HEAT SINKS ARE USED TO STOP HEAT BUILD-UP IN DIODES. HEAT SINKS ARE LARGE PIECES OF METAL. HEAT SINKS CARRY THE HEAT OF THE DIODE AND GIVE IT OFF INTO THE AIR.

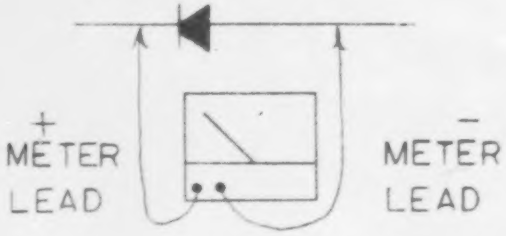
DIODES ARE RATED ACCORDING TO PEAK INVERSE VOLTAGE. THIS RATING TELLS US HOW MUCH VOLTAGE CAN BE APPLIED BEFORE THE DIODE BREAKS DOWN. WHEN THE DIODE BREAKS DOWN CURRENT WILL FLOW IN THE REVERSE DIRECTION. THIS IS CALLED THE ZENER EFFECT. A REGULAR DIODE IS DESTROYED WHEN VOLTAGE HIGHER THAN THE PEAK INVERSE VOLTAGE RATING IS APPLIED.

THERE IS A SPECIAL TYPE OF DIODE CALLED A ZENER DIODE. IT IS MADE TO HANDLE VOLTAGES ABOVE ITS PEAK INVERSE VOLTAGE RATING. IT DOES THIS BY LETTING THE CURRENT FLOW IN THE REVERSE DIRECTION.

AN OHMMETER CAN BE USED TO CHECK A DIODE. IF IT IS "GOOD" IT WILL HAVE A NEAR-ZERO RESISTANCE READING IN THE DIRECTION OF CURRENT FLOW AND A HIGH RESISTANCE READING IN THE OTHER DIRECTION. THE PICTURES BELOW SHOW HOW TO HOOK UP AN OHMMETER TO CHECK A DIODE.



IF DIODE IS "GOOD," YOU WILL GET THIS LOW READING.



IF DIODE IS "GOOD," YOU WILL GET THIS HIGH READING.

STUDY QUESTIONS

UNIT: 05 DIODES, PART I

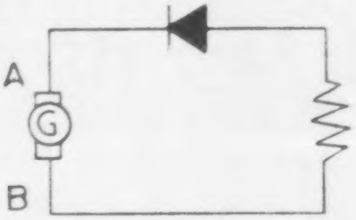
1. DRAW THE SYMBOL FOR A DIODE. LABEL THE CATHODE (-) AND THE ANODE (+).

2. A FAULTY DIODE DOES NOT CONDUCT CURRENT. CIRCLE THE CORRECT ANSWER. TRUE FALSE

3. WHICH OF THE FOLLOWING CAN BREAK DOWN A DIODE?
   (A) HEAT
   (B) A LARGE REVERSE VOLTAGE
   (C) A FAULTY HEAT SINK

4. ONLY VERY LARGE DIODES CAN BE USED TO BLOCK CURRENT. CIRCLE THE CORRECT ANSWER. TRUE FALSE

5. LOOK AT THE DIAGRAM BELOW.



WHAT DO YOU HAVE IF THE POLARITY OF THE VOLTAGE AT A IS POSITIVE AND AT B IS NEGATIVE? CIRCLE THE CORRECT LETTER.

(A) REVERSE BIAS

(B) FORWARD BIAS

6. HOW ARE DIODES SPECIFIED FOR PURCHASE?

   (A) FORWARD CURRENT

   (B) PEAK INVERSE VOLTAGE

   (C) BOTH OF THE ABOVE

7. WHAT KIND OF DIODE IS MADE TO OPERATE AT VOLTAGES ABOVE ITS PEAK INVERSE VOLTAGE?

EXPERIMENT #1
TESTING DIODES

UNIT: 05 DIODES, PART I

DO THE FOLLOWING:

1. DRAW THE SYMBOL FOR A DIODE. LABEL ALL PARTS.

2. GET AN OHMMETER. GET SEVERAL DIODES FROM THE INSTRUCTOR. CHECK EACH DIODE WITH THE OHMMETER. CHECK BELOW IF THEY ARE "GOOD" OR "BAD."

   DIODE #1 ____ GOOD ____ BAD
   DIODE #2 ____ GOOD ____ BAD
   DIODE #3 ____ GOOD ____ BAD
   DIODE #4 ____ GOOD ____ BAD
   DIODE #5 ____ GOOD ____ BAD

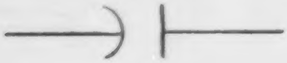
3. WHICH OF THE FOLLOWING IS CORRECT? CIRCLE THE CORRECT LETTER.
   (A) CURRENT FLOWS FROM ANODE TO CATHODE IN A DIODE.
   (B) CURRENT FLOWS FROM CATHODE TO ANODE IN A DIODE.

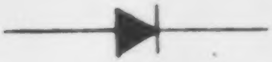
4. A FAULTY DIODE WILL DO WHICH OF THE FOLLOWING? CIRCLE THE CORRECT LETTER.
   (A) WILL LET CURRENT FLOW IN ONE DIRECTION.
   (B) WILL LET CURRENT FLOW IN BOTH DIRECTIONS.
   (C) WILL LET CURRENT FLOW IN EITHER DIRECTION.

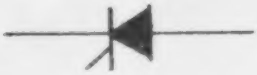
STUDENT EXAMINATION

Unit: 05 Diodes, Part I

1. Which of these symbols is the one for a diode?

(A) 

(B) 

(C) 

2. What meter is used to check a diode? Circle the correct letter.

(A) Voltmeter
(B) Wattmeter
(C) Ohmmeter

3. Reverse bias happens when a diode is connected to (check one):

____ Permit current to flow
____ Prevent or block current from flowing

4. A block of metal used to give off the heat produced by a diode is called a ______________________.

5. Forward bias happens when a diode is connected to (check one):

____ Permit current to flow
____ Prevent or block current from flowing

6. The positive end of a diode is the (check one):

_____ Anode

_____ Cathode

7. The negative end of a diode is the (check one):

_____ Anode

_____ Cathode

8. Diodes that are made to operate at voltages higher than their Peak Inverse Voltage are called (check one):

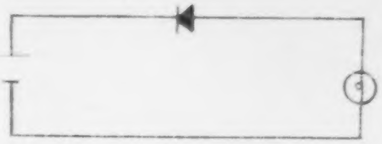
_____ Silicon diodes

_____ SCR's

_____ Triacs

_____ Zeners

9. Will current flow in this circuit? Circle the correct answer. Yes No



10. Go to the display table. Get a diode. Take the diode and your examination to the instructor.

STUDENT COMPETENCY SHEET #1

Unit: 05 Diodes, Part II

Competency Statement: Explains uses for diodes.

Performance Objective:

Action: You will answer questions about the main uses for diodes.

Conditions: You have 15 minutes to do this. You may not use references.

Standard: All your answers must be correct.

Learning Activities:

1. Get Student Handout #1, "Diodes: Uses," from the instructor. Read it.
2. Get Experiment #1, "Diodes: Rectifiers," from the instructor. Complete all steps in the experiment.
3. Tell the instructor when you are ready for the examination. Complete the examination.

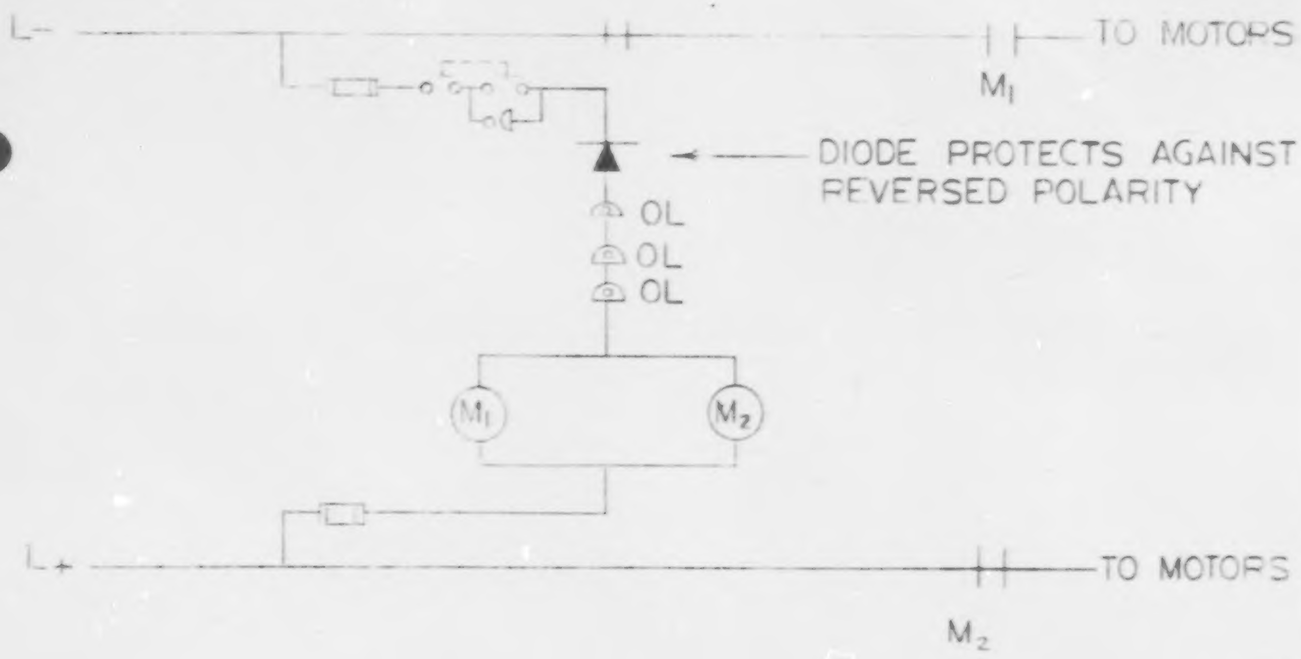
STUDENT HANDOUT #1

DIODES: USES

UNIT: 05 DIODES, PART II

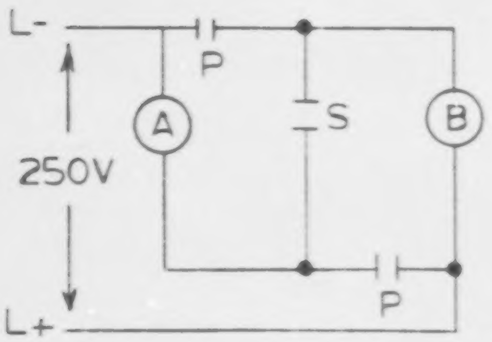
IN THIS HANDOUT WE WILL STUDY SOME OF THE USES OF DIODES.

ONE OF THE SIMPLEST USES OF DIODES IS TO BLOCK CURRENT. THE CONTROL CIRCUIT IN THE DIAGRAM BELOW HAS A DIODE WHICH IS USED FOR BLOCKING. THE DIODE KEEPS THE EQUIPMENT FROM OPERATING UNDER REVERSED POLARITY CONDITIONS.

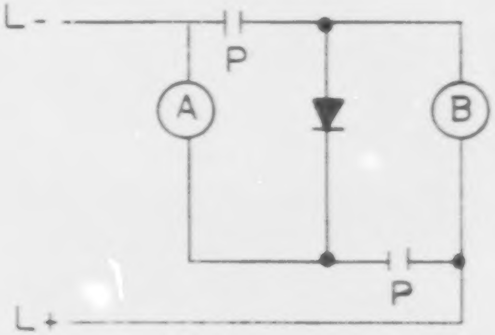


DIODE PROTECTS AGAINST REVERSED POLARITY

ANOTHER USE FOR DIODES IN DC MINING EQUIPMENT IS TO REPLACE CONTACTORS. IN CIRCUIT A BELOW CONTACTORS ARE USED. IN CIRCUIT B A DIODE AND A CONTACTOR ARE USED.



CIRCUIT A



CIRCUIT B

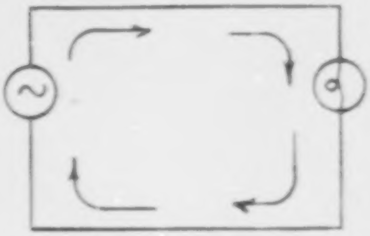
IN CIRCUIT A THE "S" CONTACTOR CLOSES AND CONNECTS THE MOTORS IN SERIES. BOTH MOTORS START AT REDUCED VOLTAGE. A TIMING RELAY CAUSES THE "S" CONTACTOR TO OPEN AND "P" CONTACTOR TO CLOSE. THIS CONNECTS THE TWO MOTORS IN PARALLEL AT FULL VOLTAGE.

IN CIRCUIT B THE "S" CONTACTOR HAS BEEN REPLACED BY A DIODE. THE MOTORS START AT REDUCED VOLTAGE JUST LIKE IN CIRCUIT A. WHEN THE TIMING RELAY CLOSES THE "P" CONTACTOR THE MOTORS ARE

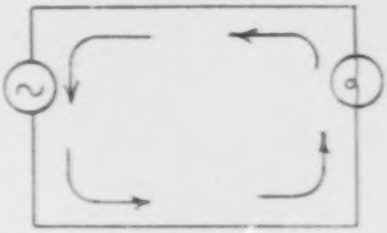
CONNECTED IN PARALLEL AT FULL VOLTAGE. THE DIODE BLOCKS CURRENT FLOW WHILE THE MOTORS ARE CONNECTED IN PARALLEL.

A THIRD USE FOR DIODES IS POWER RECTIFICATION. DIODES HAVE BECOME ONE OF THE BEST WAYS AVAILABLE TO RECTIFY AC TO DC.

ALTERNATING CURRENT CHANGES ITS DIRECTION 120 TIMES EACH SECOND. THIS MEANS THAT THE CURRENT WILL FIRST FLOW IN ONE DIRECTION. THIS IS SHOWN IN CIRCUIT A BELOW. THEN THE CURRENT WILL REVERSE ITSELF AND START FLOWING IN THE OTHER DIRECTION. THIS IS SHOWN IN CIRCUIT B.

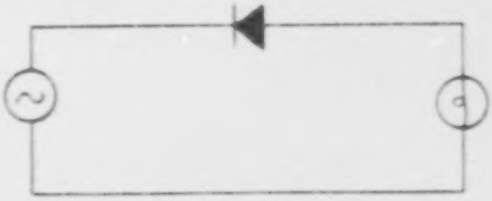


CIRCUIT A

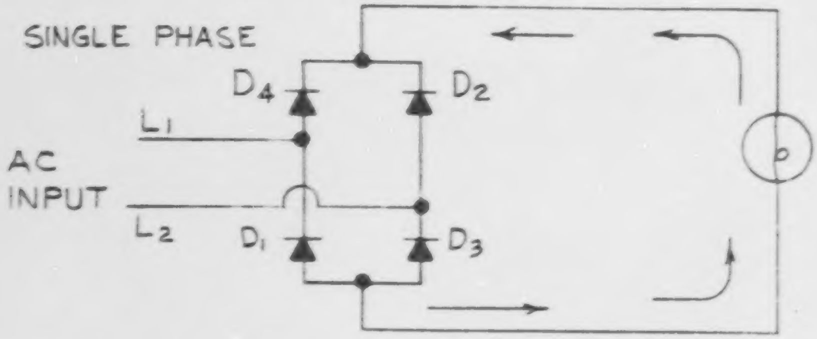


CIRCUIT B

BECAUSE A DIODE WILL BLOCK CURRENT FLOW IT CAN BE USED TO ALLOW CURRENT TO FLOW IN ONLY ONE DIRECTION. THIS RECTIFIES AC TO DC. THE CIRCUIT BELOW SHOWS HOW A DIODE CAN BE CONNECTED TO DO THIS. THIS IS CALLED HALF-WAVE RECTIFICATION. THIS IS BECAUSE THE LAMP GETS CURRENT ONLY HALF THE TIME. DURING THAT HALF OF THE TIME NO CURRENT IS FLOWING.

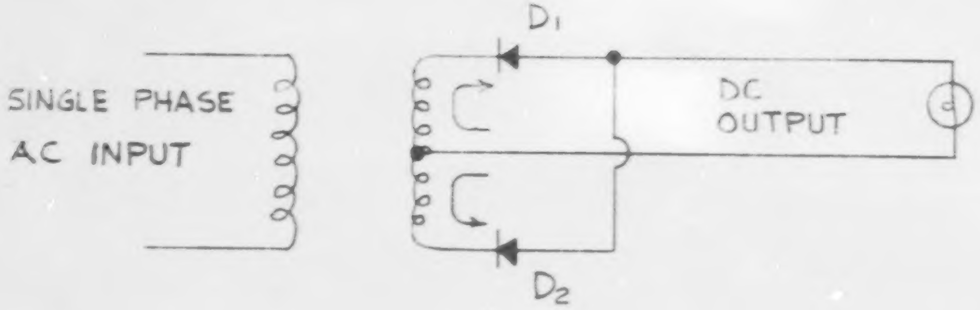


IF WE USE FOUR DIODES WE CAN GET FULL-WAVE RECTIFICATION. THE CIRCUIT BELOW SHOWS THIS. IT MEANS THE LAMP GETS CURRENT AT ALL TIMES.



IN THE CIRCUIT ABOVE CURRENT FROM L_1 FLOWS THROUGH D_1 THROUGH THE LAMP, AND RETURNS THROUGH D_2 TO THE OTHER SIDE OF THE AC SOURCE. CURRENT FROM L_2 FLOWS THROUGH D_2, THROUGH THE LAMP, AND RETURNS TO THE POWER SOURCE THROUGH D_4.

ANOTHER WAY TO GET FULL-WAVE RECTIFICATION IS BY USING A TRANSFORMER WITH A CENTER-TAPPED WINDING. ONLY TWO DIODES ARE NEEDED. THE CIRCUIT ON THE NEXT PAGE SHOWS THIS.


D1
SINGLE PHASE
AC INPUT
DC
OUTPUT
D2

IN THE CIRCUIT ABOVE CURRENT FLOWS DURING ONE-HALF OF THE AC CYCLE THROUGH D_1, THROUGH THE LAMP, AND RETURNS THROUGH THE CENTER TAP. DURING THE OTHER HALF OF THE CYCLE IT FLOWS THROUGH D_2, THROUGH THE LAMP, AND RETURNS THROUGH THE CENTER TAP.

EXPERIMENT #1
RECTIFIERS

Unit: 05 Diodes, Part II

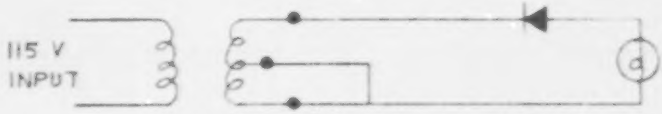
Required Material:

4 - Diodes
1 - Transformer, tapped winding
1 - Lamp
1 - VOM
Several small leads

Procedure:

1. Get all material and find a place to work.

2. Construct the half-wave rectifier shown below.

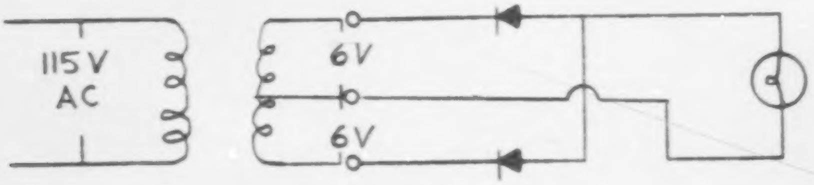


   A. Measure the AC voltage at the secondary terminal of the transformer.

   B. Measure the DC voltage at the lamp. Reverse the meter leads to prove the voltage is DC.

   C. Was there a difference in the AC and DC voltage readings? Why?

3. CONSTRUCT THE FULL-WAVE RECTIFIER SHOWN BELOW.



A. MEASURE THE SECONDARY VOLTAGE AT THE TRANSFORMER.

B. MEASURE THE DC VOLTAGE AT THE LAMP. REVERSE THE METER LEADS TO PROVE THE VOLTAGE IS DC.

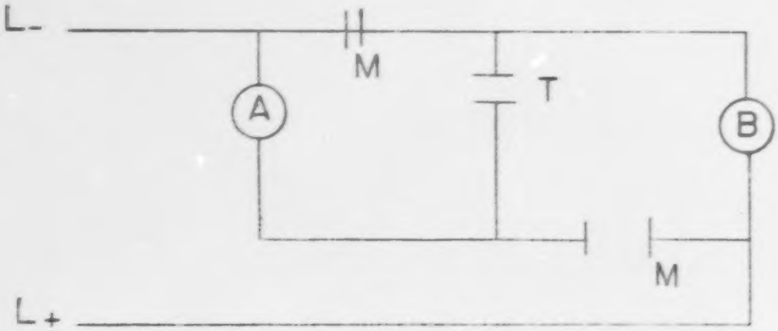
C. WAS THERE A DIFFERENCE BETWEEN THE AC AND DC VOLTAGES? WHY?

D. IS THE DC OUTPUT OF THIS RECTIFIER HIGHER THAN THE FIRST ONE? WHY?

STUDENT EXAMINATION

UNIT: 05 DIODES, PART II

1. LOOK AT THE CIRCUIT BELOW.



A. WHERE WOULD YOU PLACE A DIODE SO THAT IT WOULD BLOCK CURRENT FLOW WHEN THE MOTORS ARE CONNECTED IN PARALLEL? DRAW IT IN THE CIRCUIT AND PLACE AN "X" THROUGH ANYTHING IT WOULD REPLACE.

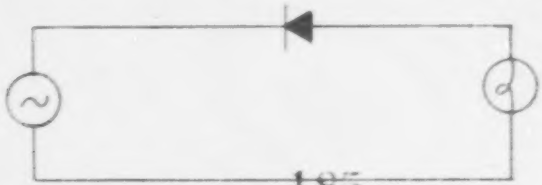
B. DOES IT MAKE ANY DIFFERENCE IF THE DIODE IS REVERSED OR FORWARD BIASED? CIRCLE THE CORRECT ANSWER.

YES NO

2. A DIODE CAN BE USED TO RECTIFY DC TO AC BECAUSE IT BLOCKS CURRENT FLOW IN ONE DIRECTION. CIRCLE THE CORRECT ANSWER.

TRUE FALSE

3. WHAT TYPE OF RECTIFICATION IS SHOWN IN THE CIRCUIT BELOW?



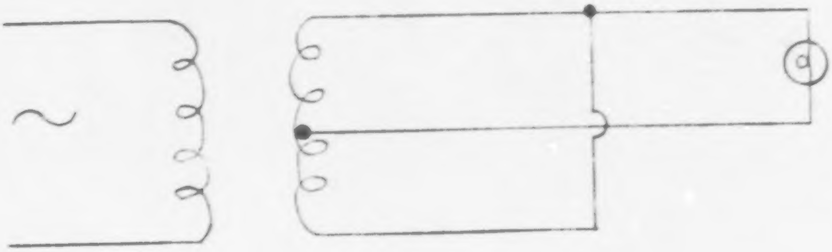
4. WHEN WILL THE LAMP GET CURRENT IN THE CIRCUIT SHOWN IN #3? CIRCLE THE CORRECT LETTER.

   A. ALL THE TIME

   B. ONE-HALF THE TIME

   C. IT WILL NOT GET CURRENT. THE DIODE WILL BLOCK CURRENT FLOW.

5. LOOK AT THE RECTIFIER BELOW.



   A. HOW MANY DIODES DO YOU NEED TO USE TO HAVE FULL-WAVE RECITIFICATION? CIRCLE THE RIGHT NUMBER.

   2 4 6

   B. DRAW THE DIODES IN THE CIRCUIT THAT WILL PROVIDE FULL-WAVE RECTIFICATION.

STUDENT COMPETENCY SHEET #1

UNIT: 06 SCR IDENTIFICATION AND SYMBOL

COMPETENCY STATEMENT: IDENTIFIES SCRS AND THEIR SYMBOL

PERFORMANCE OBJECTIVE:

ACTION:	YOU WILL IDENTIFY AN SCR BY WHAT IT LOOKS LIKE AND ANSWER QUESTIONS ABOUT ITS SYBMOL AND FEATURES.
CONDITIONS:	YOU HAVE 15 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.
STANDARD:	ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GO TO A DISPLAY TABLE SET UP BY THE INSTRUCTOR. LOOK AT THE SCRS THAT ARE ON THE TABLE.
2. GET STUDENT HANDOUT #1, "SCR: IDENTIFICATION AND SYMBOL," FROM THE INSTRUCTOR. READ IT.
3. TELL YOUR INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

SCR: IDENTIFICATION AND SYMBOL

UNIT: 06 SCR: IDENTIFICATION AND SYMPOL

AN SCR (SILICON CONTROLLED RECTIFIER) IS A SOLID STATE DEVICE THAT LOOKS A LOT LIKE A DIODE. THERE IS ONE BIG DIFFERENCE. THE SCR HAS AN EXTRA LEAD CALLED THE "GATE" LEAD.

LIKE THE DIODE, THE SCR IS A RECTIFYING DEVICE. THAT IS, IT WILL PERMIT CURRENT TO FLOW THROUGH IT IN ONLY ONE DIRECTION.

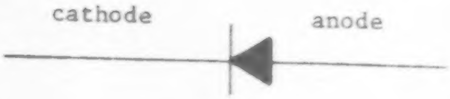
THE SCR DIFFERS FROM A DIODE IN OPERATION. AS ITS NAME IMPLIES, THE SCR CAN BE CONTROLLED. IT ACTS LIKE A SWITCH AND AS A DIODE.

WHEN ACTING LIKE A SWITCH, THE SCR CAN BE IN ONE OF TWO ELECTRICAL STATES,"OFF" OR "ON".

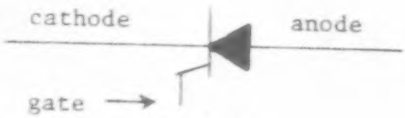
WHEN THE SCR IS "OFF" IT ACTS LIKE AN OPEN SWITCH. IT BLOCKS CURRENT FROM FLOWING THROUGH IT IN EITHER DIRECTION.

WHEN THE SCR IS "ON" IT ACTS LIKE A REGULAR DIODE. IT ALLOWS CURRENT FLOW IN ONE DIRECTION, BUT BLOCKS CURRENT FLOW IN THE OTHER DIRECTION.

Since the SCR resembles the diode in appearance, and since it functions as a diode when "turned on," the symbol for an SCR looks like the symbol for a diode. The only difference is that the SCR symbol shows the extra "gate" lead.



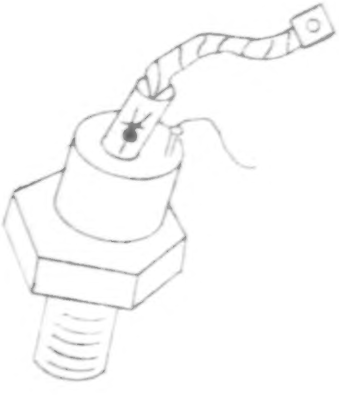
DIODE SYMBOL



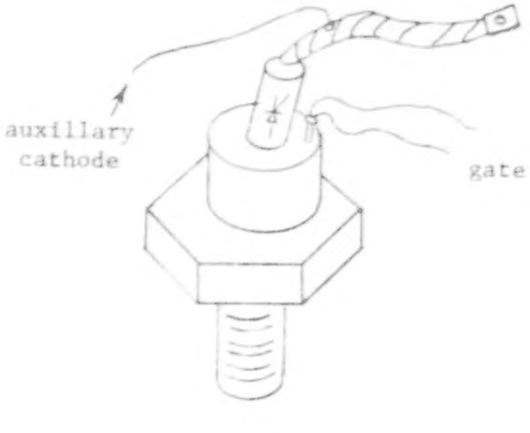
SCR SYMBOL

Some SCR's may have extra leads. You may have noticed this during trips to the display table.

All SCR's have at least three (3) terminals. The anode, the cathode, and the gate.



A



B

If an SCR has two gate leads like the one in Figure B, it does not mean that the SCR has two different gate terminals. It has two gate leads which are connected to the same gate terminal.

AN AUXILLIARY CATHODE LEAD IS A LEAD THAT IS ATTACHED TO THE CATHODE OF AN SCR FOR CONTROL PURPOSES. THE SCR DOES NOT HAVE TWO CATHODES. INSTEAD IT HAS TWO LEADS ATTACHED TO THE CATHODE TERMINAL. ONE LEAD IS USED TO CARRY HEAVY MOTOR CURRENT, THE OTHER LEAD IS FOR CONTROL CIRCUITS.

IT IS EASY TO TELL THE DIFFERENCE BETWEEN THE AUXILLIARY CATHODE LEAD AND THE GATE LEAD.

THE GATE LEAD ATTACHES DIRECTLY TO A SEPARATE TERMINAL ON THE BODY OF THE SCR. IT IS ALSO A WHITE LEAD.

THE AUXILLIARY CATHODE LEAD IS SPLICED ONTO THE LARGE CATHODE LEAD. IN MOST CASES YOU CAN SEE THIS SPLICE. THE AUXILLIARY CATHODE WILL ALWAYS BE A RED LEAD.

SUMMARY:

SCR'S ARE SIMILAR TO DIODES IN SEVERAL WAYS.

1. THEY ARE AVAILABLE IN SEVERAL SHAPES AND SIZES.

2. THEY ARE AVAILABLE WITH THE CATHODE AT EITHER END.

3 THEY ARE BOTH RECTIFYING DEVICES.

SOME DIFFERENCES BETWEEN THE SCR AND THE DIODE ARE:

1. THE SCR HAS 3 TERMINALS. THE DIODE ONLY HAS TWO.

2. THE SCR CAN BE CONTROLLED. THE DIODE CANNOT.

3. THE SCR CAN BE USED TO BLOCK CURRENT IN BOTH DIRECTIONS. THE DIODE WILL ONLY BLOCK CURRENT IN ONE DIRECTION.

STUDENT EXAMINATION #1

Unit: 06 SCR Identification and Symbol

1. What is the difference that we can see between an SCR and a diode?

2. We must be able to identify the SCR by how it looks. What else is on the SCR to help identify it?

3. When an SCR is on, current will flow through it in
   A. Both directions
   B. Only one direction

4. List the names for the three terminals on an SCR
   A. ____________________
   B. ____________________
   C. ____________________

5. If an SCR has an extra lead, it is most likely an auxilliary ____________________ lead.

6. Draw the symbol of an SCR and name its parts.

STUDENT COMPETENCY SHEET #2

UNIT: 06 SCR OPERATION

COMPETENCY STATEMENT: EXPLAINS SCR OPERATION

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ON SCR OPERATION.

CONDITIONS: YOU HAVE TEN MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #2, "SCR OPERATION-ON" FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END.
2. GET STUDENT HANDOUT #3, "SCR OPERATION-OFF" FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
3. GET EXPERIMENT 1, "SCR OPERATION," FROM THE INSTRUCTOR. DO ALL STEPS IN THE EXPERIMENT.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #2

UNIT: 06 SCR OPERATION - ON

YOU HAVE LEARNED THE FOLLOWING THINGS ABOUT AN SCR:

1. WHAT AN SCR LOOKS LIKE;
2. HOW TO DRAW THE SYMBOL FOR AN SCR;
3. THAT AN SCR IS A RECTIFYING DEVICE; AND,
4. THAT AN SCR CAN BE CONTROLLED.

NOW WE WILL LEARN HOW TO CONTROL THE SCR.

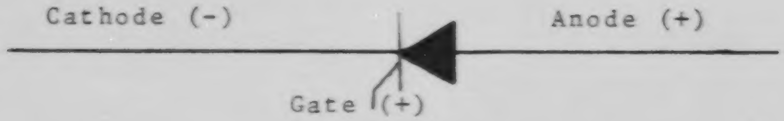
WHEN AN SCR IS OFF IT IS SAID TO BE IN ITS "BLOCKING" STATE. IT ACTS LIKE A SWITCH THAT IS IN THE "OFF" POSITION. CURRENT CANNOT FLOW THROUGH AN SCR WHEN IT IS IN ITS BLOCKING STATE.

WHEN AN SCR IS ON IT IS SAID TO BE "IN CONDUCTION," OR "TURNED ON." IN THIS STATE IT ACTS LIKE A SWITCH IN THE ON POSITION. IT WILL PERMIT CURRENT TO FLOW THROUGH IT. IT ALSO ACTS LIKE A DIODE TOO. WHEN AN SCR IS TURNED ON CURRENT CAN PASS THROUGH IT IN ONLY ONE DIRECTION.

THE DIRECTION OF CURRENT FLOW THROUGH THE SCR IS ALWAYS FROM THE CATHODE END TO THE ANODE END.

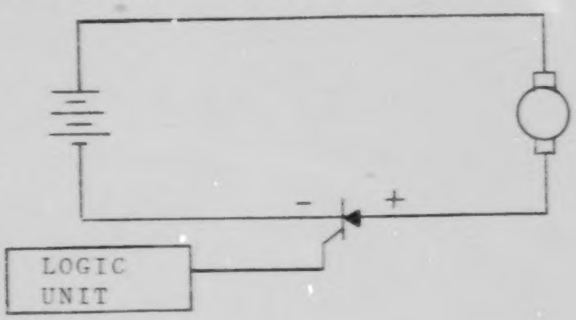
THE GATE LEAD IS USED TO TURN THE SCR ON. WHEN THE GATE LEAD IS ENERGIZED, THE SCR "FIRES" INTO CONDUCTION.

SPECIAL CONDITIONS MUST EXIST IN ORDER TO "FIRE" THE SCR.



THE FOLLOWING CONDITIONS MUST EXIST BEFORE AN SCR WILL TURN ON:

1. THE CATHODE MUST BE NEGATIVE.
2. THE ANODE MUST BE POSITIVE.
3. THE GATE LEAD MUST BE POSITIVE.



IN THE ABOVE CIRCUIT, THE NEGATIVE SIDE OF THE POWER SOURCE IS CONNECTED TO THE SCR CATHODE AND THE POSITIVE SIDE OF THE POWER SOURCE IS CONNECTED TO THE SCR ANODE. THE SCR IS SAID TO BE CONNECTED FORWARD BIASED. THIS IS THE CORRECT CONNECTION FOR CORRECT SCR OPERATION.

IF THE LOGIC UNIT CAUSES THE SCR GATE LEAD TO BE POSITIVE THE SCR WILL "TURN ON." CURRENT WILL THEN FLOW THROUGH THE SCR AND THE MOTOR WILL OPERATE.

ONCE AN SCR IS TURNED ON THE GATE LEAD CAN BE DISCONNECTED. THE SCR WILL STAY IN ITS "ON" STATE AS LONG AS CURRENT FLOWS THROUGH IT.

THE ONLY WAY TO "TURN OFF" AN SCR IS TO INTERRUPT CURRENT FLOW THROUGH IT OR TO DECREASE THE CURRENT THROUGH IT TO A VERY LOW LEVEL.

THE TERM "HOLDING CURRENT" REFERS TO THE LEAST AMOUNT OF CURRENT NECESSARY TO KEEP THE SCR IN ITS "ON STATE."

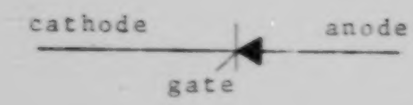
STUDY QUESTIONS

SCR OPERATION-ON

UNIT: 06 SCR OPERATION

1. WHAT IS MEANT WHEN IT IS SAID THAT AN SCR IS "IN CONDUCTION?"

2. LOOK AT THE DRAWING BELOW.



FOR THE SCR TO "FIRE," WHAT CONDITIONS MUST EXIST?

A. CATHODE MUST BE ____________

B. ANODE MUST BE ______________

C. GATE MUST BE _______________

3. NAME TWO WAYS TO "TURN OFF" AN SCR

A.

B.

4. WHAT IS MEANT BY THE TERM "HOLDING CURRENT?"

STUDENT HANDOUT #3

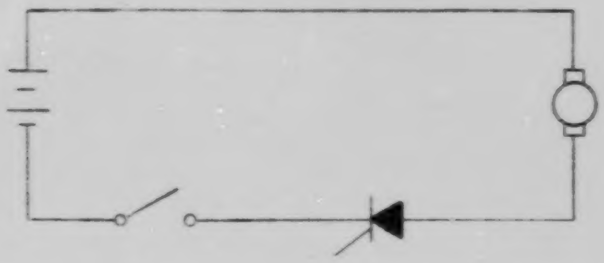
UNIT: 06 SCR OPERATION - OFF

SO FAR, YOU HAVE LEARNED MANY THINGS ABOUT AN SCR. FOR EXAMPLE, YOU NOW KNOW:

1. WHAT IT LOOKS LIKE,
2. WHAT ITS SYMBOL LOOKS LIKE,
3. THE CONDITIONS WHICH MUST EXIST IN ORDER TO TURN IT ON, AND
4. YOU HAVE LEARNED THAT ONCE THE SCR IS TURNED ON IT WILL STAY ON AS LONG AS CURRENT IS FLOWING THROUGH IT.

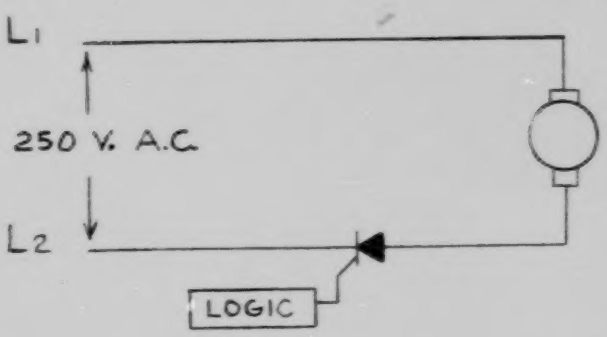
IN THIS LESSON YOU WILL LEARN SOME OF THE GENERAL PRINCIPLES USED TO TURN THE SCR OFF.

IF AN SCR IS ON IT WILL REMAIN ON AS LONG AS CURRENT FLOWS THROUGH IT. IF THE CURRENT IS INTERRUPTED IT WILL AUTOMATICALLY RETURN TO ITS BLOCKING, OR OFF STATE.



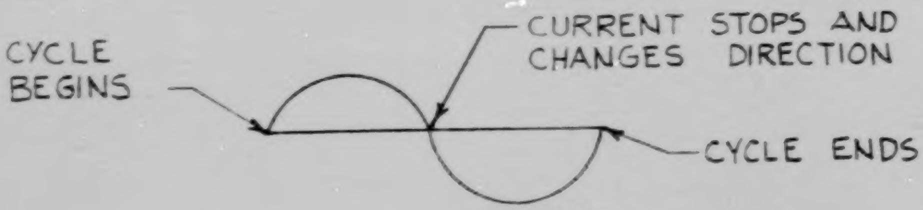
IN THE CIRCUIT ABOVE, A SWITCH IS USED TO INTERRUPT THE CURRENT FLOW THROUGH THE SCR. WHEN THE CURRENT FLOW IS STOPPED THE SCR AUTOMATICALLY TURNS OFF.

THIS IS NOT A PRACTICAL CIRCUIT. FIRST, THE CIRCUIT IS DC AND DOES NOT NEED A RECTIFYING DEVICE. SECONDLY, IF THE OFF SWITCH IS NEEDED TO TURN THE CIRCUIT OFF THEN IT CAN BE USED TO TURN IT ON ALSO. THIS MEANS THAT WE DO NOT NEED THE SCR AS A SWITCHING DEVICE. BELOW IS A CIRCUIT WHICH IS VERY PRACTICAL.



IN THIS CIRCUIT, THE SCR IS USED BOTH AS A SWITCHING DEVICE AND AS A RECTIFIER. ALTERNATING CURRENT IS USED AS A POWER SOURCE.

ALTERNATING CURRENT IS CONTINUALLY CHANGING ITS DIRECTION. IN FACT, 60 CYCLE AC WILL CHANGE ITS DIRECTION 120 TIMES EACH SECOND. IF AC CHANGES ITS DIRECTION IT MUST STOP FLOWING MOMENTARILY WHILE THE CHANGE IS TAKING PLACE. (SEE BELOW)

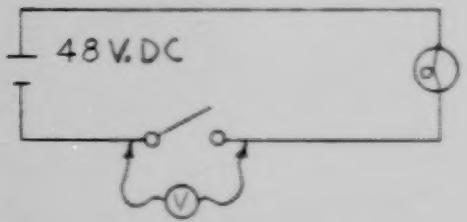


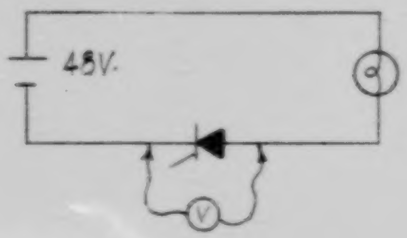
If the logic unit fires the SCR at the beginning of the cycle the SCR will automatically turn off at the end of the positive half. This is because the current flowing in the circuit drops to zero for a brief instant.

To turn off an SCR when it is used in an AC circuit we only need to turn off the logic unit (interrupt the gate).

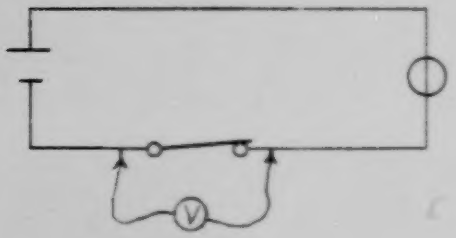
When an SCR is used as a switching device in a DC circuit special arrangements must be made to turn the SCR off. Let's take a look at how a capacitor can be used to turn off the SCR.

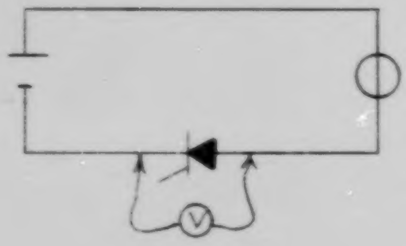
To better understand how the capacitor can be used to turn the SCR off we will first compare the SCR with a simple switch.



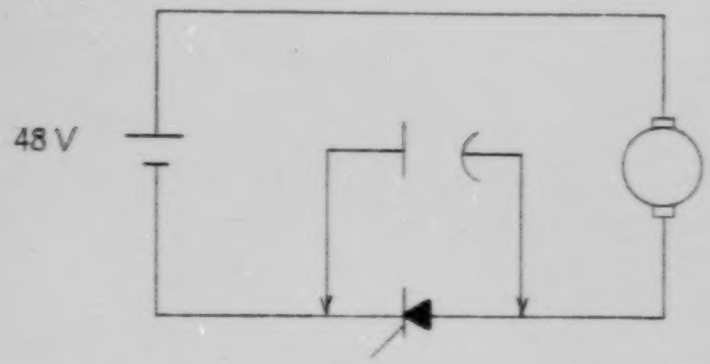


When the SCR or a switch is open, the voltage that appears across them is equal to the line voltage. The voltmeters above will have 48 volts.

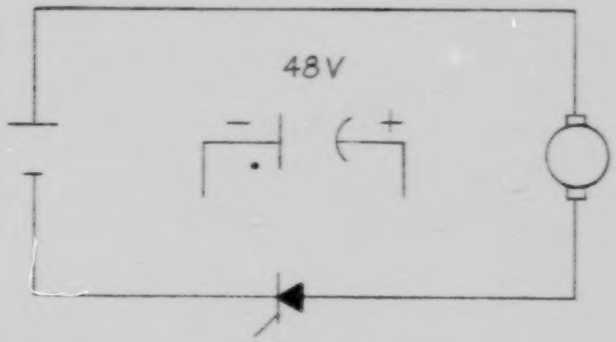




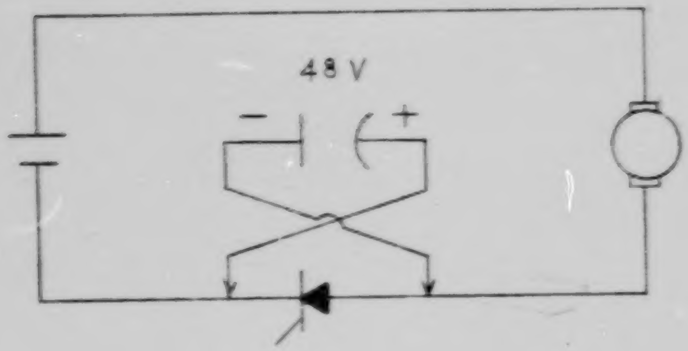
IF THE SWITCH IS CLOSED THE VOLTAGE ACROSS IT DROPS TO ZERO. IF THE SCR IS IN CONDUCTION THE VOLTAGE ACROSS IT DROPS TO NEARLY ZERO. SINCE THE SCR HAS SOME RESISTANCE A SLIGHT VOLTAGE, USUALLY 5 VOLTS OR LESS, WILL APPEAR ACROSS IT.



IN THE CIRCUIT ABOVE A CAPACITOR IS CHARGED UP TO THE LINE VOLTAGE WHILE THE SCR IS OFF. THE CAPACITOR IS THEN DISCONNECTED AND ALLOWED TO STORE ITS CHARGE.



THE CIRCUIT ABOVE SHOWS THE SCR TURNED ON AND THE MOTOR RUNNING. THE CAPACITOR IS CHARGED.



IF THE CAPACITOR IS CONNECTED ACROSS THE SCR AGAIN, BUT IN REVERSED POLARITY, THE SCR WILL TURN OFF.

THE SCR TURNS OFF BECAUSE THE REVERSE VOLTAGE PRODUCED BY THE CAPACITOR IS HIGHER THAN THE SCR VOLTAGE. THIS MOMENTARILY CAUSES THE SCR TO BECOME REVERSE BIASED. THE CATHODE IS NOW POSITIVE AND THE ANODE IS NEGATIVE.

LATER IN THE COURSE, WE WILL LEARN HOW THIS METHOD IS USED IN DC MINING EQUIPMENT TO TURN OFF THE SCR.

SUMMARY:

1. TO FIRE AN SCR IT MUST BE CONNECTED FORWARD BIASED.
2. ONCE FIRED INTO CONDUCTION IT WILL REMAIN IN CONDUCTION AS LONG AS CURRENT FLOWS THROUGH IT.
3. AN SCR WILL AUTOMATICALLY TURN OFF:
    - A. WHEN CURRENT FLOWING THROUGH IT IS INTERRUPTED.
    - B. WHEN CURRENT FLOWING THROUGH IT DROPS BELOW THE HOLDING CURRENT.
    - C. ANYTIME IT IS REVERSED BIASED.

STUDY QUESTIONS

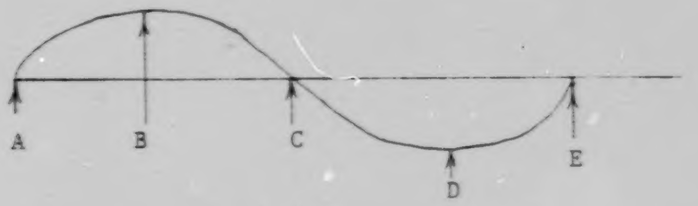
SCR OPERATION - OFF

1. AN SCR IS "FIRED." THE GATE LEAD IS DISCONNECTED. THE SCR CONTINUES TO CONDUCT. WHAT IS THE POWER SOURCE? CIRCLE THE CORRECT LETTER.

   A. AC

   B. DC

2. LOOK AT THE AC SINE WAVE BELOW.



   IF AN SCR "FIRES" AT POINT A, WHEN WILL IT "TURN OFF?" CIRCLE THE CORRECT ANSWER.

   A. POINT B

   B. POINT C

   C. POINT D

   D. POINT E

3. WHY DOES AN SCR "TURN OFF" WHEN IT BECOMES MONEMTARILY REVERSED BIASED?

4. CAN ANY SIZE CAPACITOR BE USED TO "TURN OFF" AN SCR? EXPLAIN YOUR ANSWER.

EXPERIMENT #1
SCR OPERATION

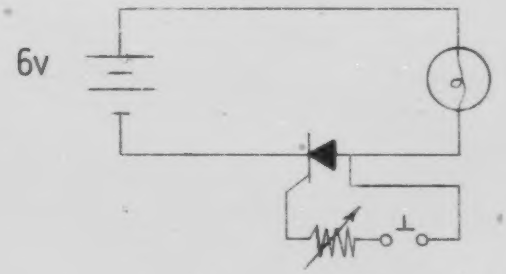
UNIT 06: SCR, OPERATION

REQUIRED MATERIAL

1 - SCR
1 - BATTERY
1 - AC POWER SOURCE
1 - LAMP
1 - RESISTOR (VARIABLE)
1 - PUSH BUTTON SWITCH
4 - 5 - SHORT LEADS

PROCEDURE:

1. GET ALL MATERIALS AND A PLACE TO WORK.
2. CONNECT THE CIRCUIT SHOWN BELOW.



3. TURN THE RESISTOR TO THE MAXIMUM RESISTANCE POSITION.
4. PRESS THE PUSH BUTTON SWITCH. IF THE LIGHT DOES NOT BURN HOLD THE BUTTON DOWN. SLOWLY DECREASE THE RESISTANCE UNTIL THE LIGHT COMES ON.

5. Release the switch. Did the light stay on?

6. Explain why the light would stay on.

7. Explain why the light would not stay on.

8. Repeat Steps 3 through 7 using the AC power source.

9. Explain the difference between AC and DC SCR operation.

10. Return all materials to the proper storage area.

STUDENT EXAMINATION #2

UNIT: 06 SCR, OPERATION

1. IN WHAT DIRECTION DOES CURRENT FLOW THROUGH AN SCR?
    - A. ANODE TO CATHODE
    - B. CATHODE TO ANODE

2. IN ORDER TO FIRE AN SCR THE GATE LEAD MUST BE ENERGIZED
    - A. NEGATIVE VOLTAGE OR PULSE
    - B. POSITIVE VOLTAGE OR PULSE

3. IF AN SCR IS TO OPERATE ITS ANODE AND CATHODE MUST BE CONNECTED
    - A. FORWARD BIASED
    - B. REVERSE BIASED

4. YOU DISCONNECT THE LEAD OF AN SCR WHILE IT IS IN OPERATION BUT THE MOTOR IT CONTROLS CONTINUES TO RUN. THE POWER SOURCE MUST BE
    - A. AC
    - B. DC

5. YOU MEASURE THE VOLTAGE ACROSS AN SCR AND FIND IT TO BE NEARLY ZERO.
    - A. THE SCR IS ON
    - B. THE SCR IS OFF

STUDENT COMPETENCY SHEET #3

UNIT 06: SCR: VOLTAGE CONTROL

COMPETENCY STATEMENT: EXPLAINS FUNCTION AND USE OF THE SCR FOR VOLTAGE CONTROL.

PERFORMANCE OBJECTIVE:

ACTION:	YOU WILL ANSWER QUESTIONS ABOUT THE FUNCTION AND USE OF THE SCR FOR VOLTAGE CONTROL.
CONDITIONS:	YOU HAVE TEN MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.
STANDARD:	ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

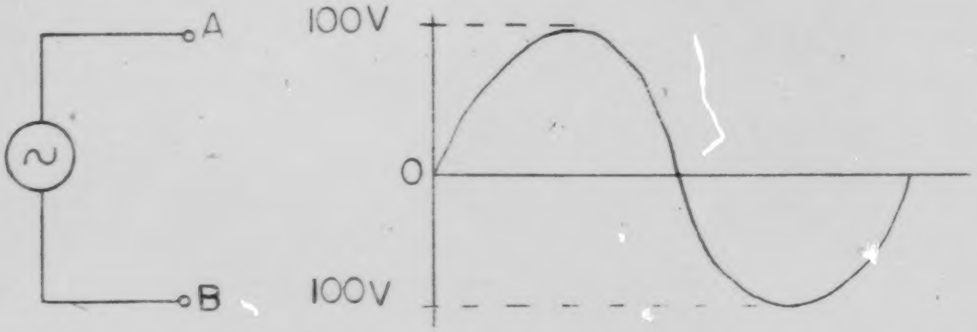
1. GET STUDENT HANDOUT #4, "SCR: VOLTAGE CONTROL," FROM THE INSTRUCTOR. READ IT.
2. TELL YOUR INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #4

UNIT 06: SCR: VOLTAGE CONTROL

WE HAVE LEARNED SEVERAL USES FOR AN SCR. THEY CAN BE USED TO CHANGE AC TO DC OR AS A HIGH SPEED SWITCH THAT WILL OPERATE THOUSANDS OF TIMES PER SECOND. PROBABLY THE MOST IMPORTANT USE OF THE SCR IS TO CONTROL THE VOLTAGE IN A CIRCUIT. IN MINING EQUIPMENT IT IS USED TO CONTROL THE VOLTAGE APPLIED TO AN AC OR DC MOTOR.

TO BETTER UNDERSTAND HOW AN SCR CAN BE USED TO CONTROL VOLTAGE LET'S REVIEW A FEW FACTS CONCERNING ALTERNATING CURRENT VOLTAGES.



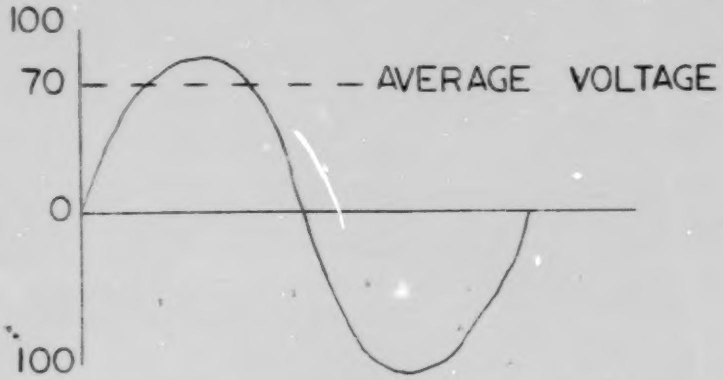
AN AC POWER SOURCE IS SHOWN ABOVE. THE SINE WAVE AT THE RIGHT IS A GRAPH OF THE OUTPUT VOLTAGE FOR ONE CYCLE OF OPERATION.

DURING THE FIRST HALF-CYCLE OF OPERATION THE OUTPUT TERMINAL "A" IS POSITIVE AND TERMINAL "B" IS NEGATIVE. AS THE ALTERNATOR BEGINS TO ROTATE THE VOLTAGE BEGINS TO BUILD UP

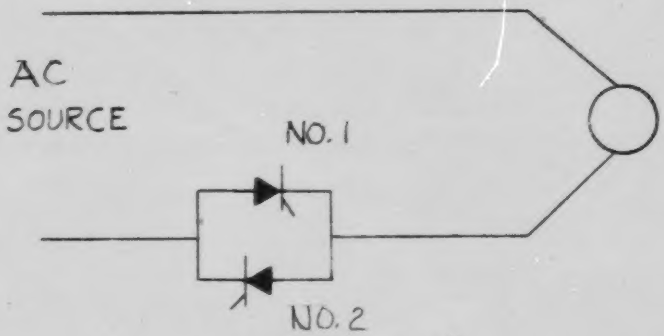
GRADUALLY TO 100 VOLTS. AS IT CONTINUES TO ROTATE THE VOLTAGE BEGINS TO DECREASE GRADUALLY TO ZERO.

THE POLARITY OF THE OUTPUT TERMINALS CHANGE AT THIS POINT. NOW, TERMINAL "A" BECOMES NEGATIVE AND TERMINAL "B" POSITIVE.

THE VOLTAGE AGAIN INCREASES GRADUALLY TO 100 VOLTS BUT IT IS NOW REVERSED. AS THE ROTATION OF THE ALTERNATOR CONTINUES THE VOLTAGE DECREASES TO ZERO AGAIN. ONE CYCLE HAS NOW BEEN COMPLETED.



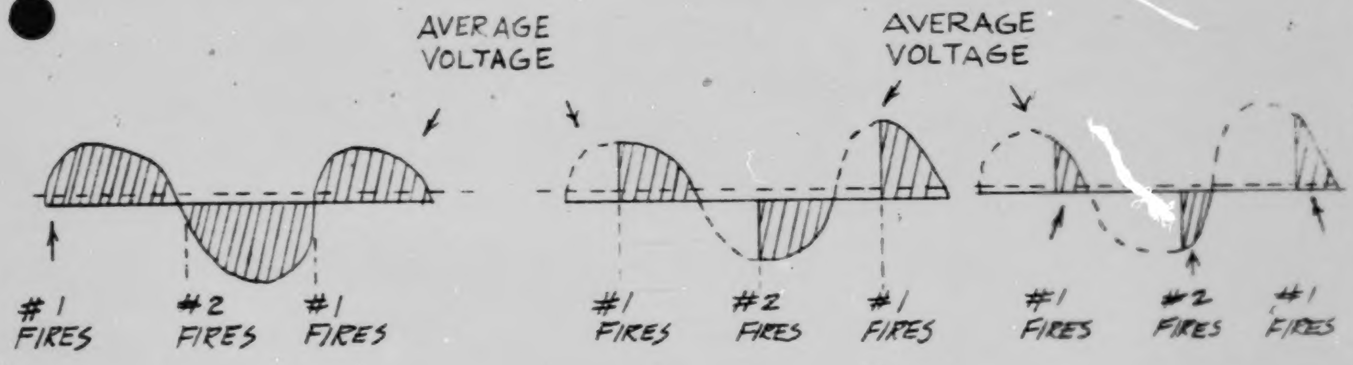
SINCE THE VOLTAGE IS CONTINUALLY INCREASING, AND DECREASING, THE AMOUNT OF VOLTAGE AVAILABLE TO DO WORK WILL BE MUCH LESS THAN THE MAXIMUM VOLTAGE. THE SINE WAVE ABOVE SHOWS THAT IF THE MAXIMUM VOLTAGE IS 100 VOLTS THE AVERAGE VOLTAGE WILL ONLY BE ABOUT 70.7 VOLTS. A VOLTMETER CONNECTED TO THIS AC POWER SOURCE WILL INDICATE 70.7 VOLTS. THE AVERAGE VOLTAGE IS WHAT MAKES A CIRCUIT OPERATE.



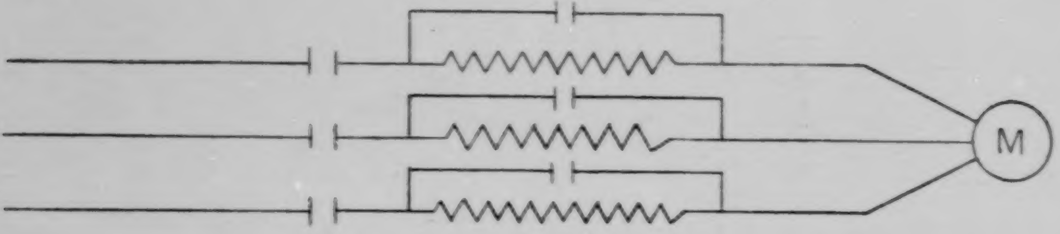
IN THE CIRCUIT ABOVE TWO SCR'S ARE USED. SCR #1 ALLOWS THE CURRENT TO FLOW IN ONE DIRECTION. SCR #2 PERMITS THE CURRENT TO FLOW IN THE OTHER DIRECTION.

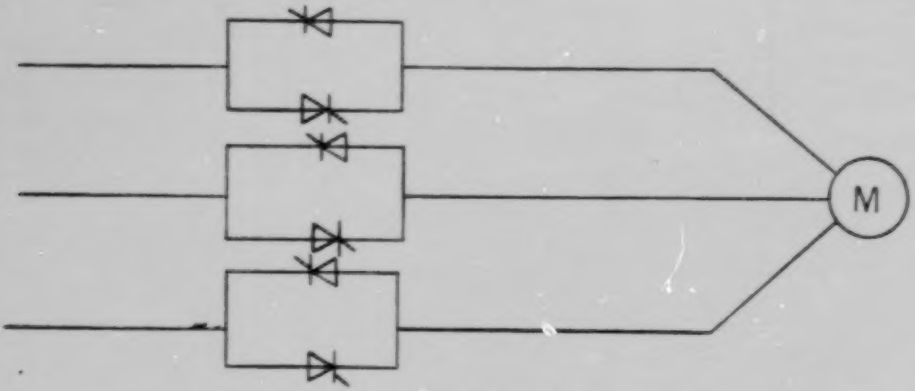
IF SCR #1 IS FIRED AT THE BEGINNING OF EACH POSITIVE HALF-CYCLE, AND SCR #2 IS FIRED AT THE BEGINNING OF EACH NEGATIVE HALF-CYCLE, FULL VOLTAGE WILL BE APPLIED TO THE MOTOR.

IF THE FIRING OF AN SCR IS DELAYED UNTIL LATER IN THE CYCLE PART OF THE AC VOLTAGE WILL BE BLOCKED. THIS WILL RESULT IN A DECREASE IN THE AVERAGE VOLTAGE AVAILABLE TO DO WORK.


AVERAGE VOLTAGE
AVERAGE VOLTAGE
#1 FIRES
#2 FIRES
#1 FIRES
#1 FIRES
#2 FIRES
#1 FIRES
#1 FIRES
#2 FIRES
#1 FIRES

ABOVE ARE SEVERAL EXAMPLES OF HOW DELAYED FIRING OF THE SCR WOULD AFFECT THE AVERAGE OR EFFECTIVE VOLTAGE IN AN AC CIRCUIT.



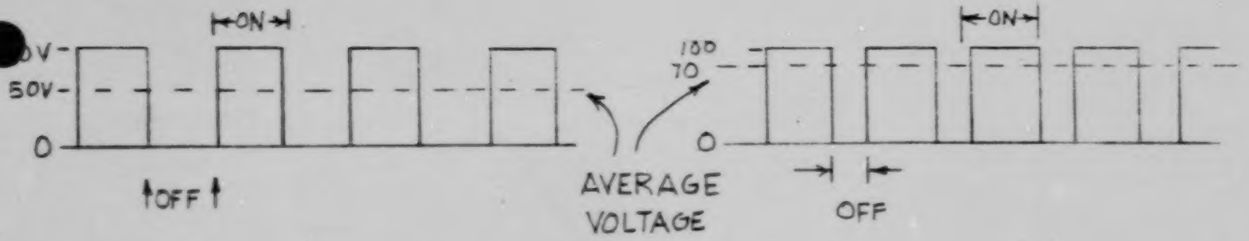


Above are two AC motor control circuits which show how the SCR can be used to replace resistors and contactors for starting and speed control. By using advanced firing circuits (logic units) the SCR can provide any voltage between zero and full voltage.

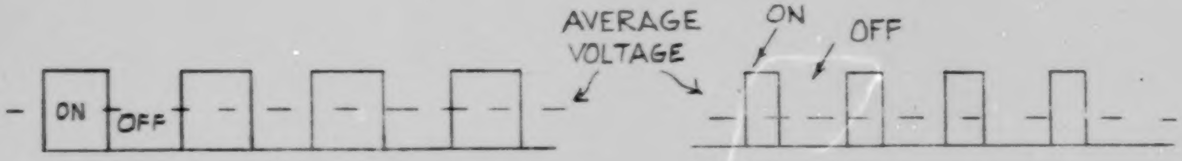
It is much more efficient since there is no heat loss and there are no moving parts to wear out.

In a DC circuit, the maximum voltage, and the average (effective) voltage are the same. The SCR changes this. By operating at high speed (turning on and off), the SCR can control the average time the voltage is applied.

The average voltage available to do work depends upon how long the SCR is on and how long it is off.



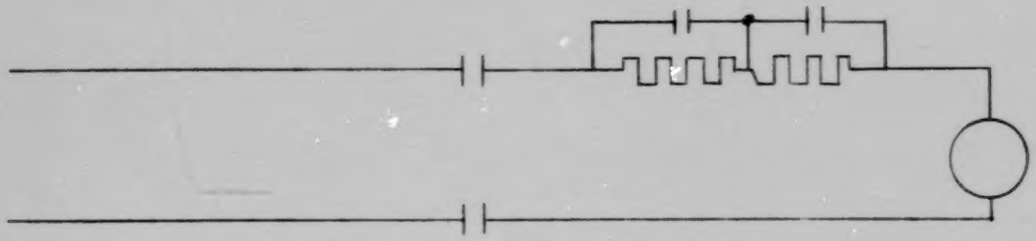
THE GRAPHS ABOVE SHOW HOW THE AVERAGE VOLTAGE VARIES WHEN THE "OFF" TIME OF THE SCR IS CHANGED. NOTE THAT THE "ON" TIME OF THE SCR IS CONSTANT. AS THE "OFF" TIME INCREASES THE AVERAGE VOLTAGE DECREASES.

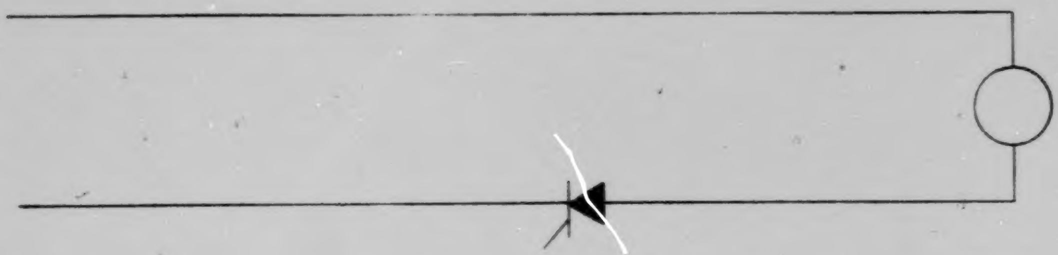


IN THESE GRAPHS, THE "OFF" TIME OF THE SCR IS CONSTANT. THE AVERAGE VOLTAGE IS CONTROLLED BY HOW LONG THE SCR IS IN CONDUCTION. AS THE "ON" TIME INCREASES THE AVERAGE VOLTAGE INCREASES.

BY CONTROLLING THE VOLTAGE APPLIED TO A DC MOTOR WE CAN CONTROL ITS SPEED. ALSO, SINCE WE CAN START THE MOTOR AT A LOW VOLTAGE, AND GRADUALLY INCREASE TO FULL VOLTAGE, A STARTING RESISTOR IS NOT NEEDED TO CONTROL THE STARTING CURRENT. AN SCR CAN BE USED TO REPLACE A STARTING RESISTOR IN A DC MOTOR CIRCUIT.

BELOW ARE TWO REDUCED VOLTAGE MOTOR STARTERS. ONE USED RESISTANCE TO CONTROL THE MOTOR VOLTAGE, THE OTHER USES THE SCR. NOTE THE DIFFERENCE IN THE NUMBER OF COMPONENTS.





IN THE CONVENTIONAL CONTROL, THREE DEFINITE STEPS ARE USED. EACH STEP OF THE STARTING SEQUENCE WILL CAUSE JERKING AND STRAINING OF GEARS.

SINCE THE SPEED CAN BE CONTROLLED GRADUALLY BY USING THE SCR, THERE WILL BE NO JERKING AND STRAINING OF GEARS. IT ALSO SAVES THE ENERGY DUE TO HEAT LOSS IN THE RESISTOR METHOD.

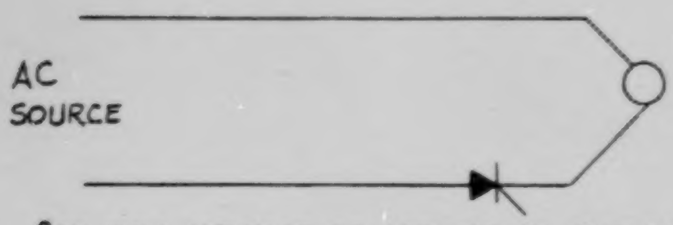
SUMMARY:

1. AN SCR CAN BE USED TO REPLACE A CONTACTOR IN A MOTOR CIRCUIT.
2. WHEN USED AS A CONTACTOR, IT IS CAPABLE OF HIGH SPEED OPERATION.
3. AN SCR HAS NO MOVING PARTS TO WEAR OUT.
4. AN SCR CAN BE USED AS A RECTIFYING DEVICE TO CHANGE AC TO DC.
5. AN SCR CAN BE USED TO CONTROL THE VOLTAGE OF A CIRCUIT.
6. AN SCR CAN BE USED TO REPLACE STARTING RESISTORS. WHEN USED THIS WAY, IT CONTROLS THE STARTING CURRENT INDIRECTLY. THAT IS, IT LOWERS THE VOLTAGE WHICH IN TURN CAUSES LESS STARTING CURRENT.

STUDENT EXAMINATION #3

UNIT 06: SCR: VOLTAGE CONTROL

1. LOOK AT THE CIRCUIT BELOW.

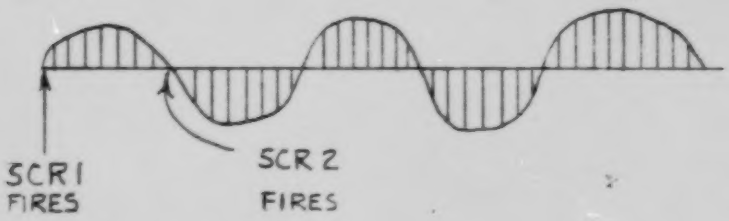


CAN FULL VOLTAGE BE APPLIED TO THE MOTOR? YES NO

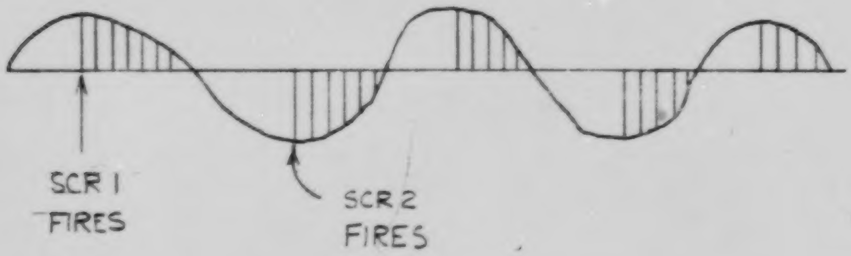
EXPLAIN YOUR ANSWER.

2. LOOK AT THE AC VOLTAGE CHARTS BELOW.

A.



B.

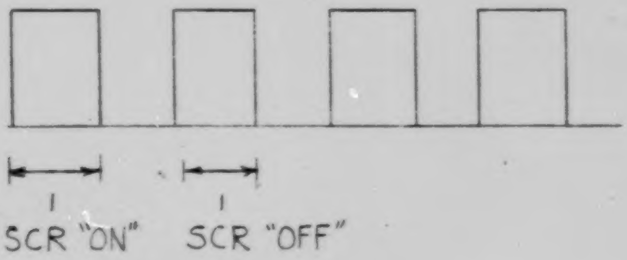


IN WHICH CASE WILL THE AVERAGE VOLTAGE AVAILABLE FOR WORK BE THE HIGHEST? A B

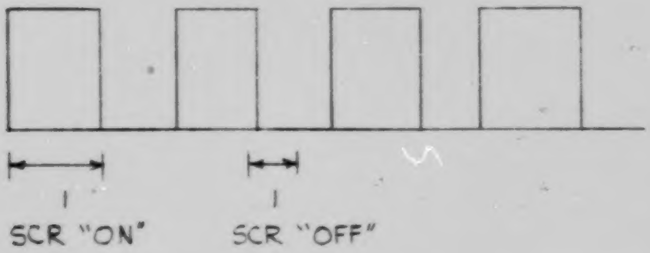
EXPLAIN YOUR ANSWER.

3. LOOK AT THE DC VOLTAGE CHARTS BELOW.

A.


SCR "ON"
SCR "OFF"

B.


SCR "ON"
SCR "OFF"

IN WHICH CASE WILL THE AVERAGE VOLTAGE AVAILABLE FOR WORK BE LESS? A B

EXPLAIN YOUR ANSWER.

STUDENT COMPETENCY SHEET #1
TRIGGERING CIRCUITS

UNIT: 07 TRIGGERING CIRCUITS

COMPETENCY STATEMENT: EXPLAINS CHARACTERISTICS OF TRIGGERING CIRCUITS

PERFORMANCE OBJECTIVE:

ACTION:	YOU WILL ANSWER QUESTIONS ABOUT TRIGGERING CIRCUITS.
CONDITIONS:	YOU HAVE 15 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.
STANDARD:	ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "RESISTANCE TRIGGERING," FROM THE INSTRUCTOR. READ IT AND THEN COMPLETE EXPERIMENT #1, "RESISTANCE TRIGGERING."

2. GET STUDENT HANDOUT #2, "RC TRIGGERING," FROM THE INSTRUCTOR. READ IT AND THEN COMPLETE EXPERIMENT #2 "RC TRIGGERING."

3. GET STUDENT HANDOUT #3 "UJT TRIGGERING," FROM THE INSTRUCTOR. READ IT AND COMPLETE EXPERIMENT #3 "UJT TRIGGERING."

STUDENT HANDOUT #1

RESISTANCE TRIGGERING

UNIT 07: TRIGGERING CIRCUITS

UP TO THIS POINT YOU HAVE STUDIED HOW VARIOUS SOLID STATE COMPONENTS AND DEVICES OPERATE AND ARE USED. THIS PART OF THE COURSE DEALS WITH THE DIFFERENT METHODS OF TRIGGERING THE SCR.

WE WILL BEGIN WITH SIMPLE CIRCUITS AND BY ADDING ONTO THESE SIMPLE CIRCUITS BUILD UP TO THE MORE COMPLICATED ONES FOUND IN MODERN CONTROLLERS. NOW LET'S BEGIN. MAKE SURE YOU HAVE COPIES OF VISUALS 1-7.

RESISTANCE TRIGGERING

THE SIMPLEST OF ALL TRIGGERING CIRCUITS HAS A NORMALLY OPEN PUSH BUTTON SWITCH CONNECTED BETWEEN THE ANODE AND GATE OF THE SCR.

LOOK AT VISUAL NUMBER 1

IN THIS CIRCUIT, A DC MOTOR IS CONNECTED TO A 48 VOLT DC BATTERY. THE P.B. SWITCH IS CONNECTED BETWEEN THE GATE AND ANODE OF THE SCR.

DEPRESSING THE SWITCH WILL CONNECT THE POSITIVE ANODE TO THE SCR GATE. THIS CAUSES THE GATE TO BECOME POSITIVE IN RELATION TO THE CATHODE. THIS CAUSES THE SCR TO "FIRE" OR "TURN ON." WHEN THE SCR FIRES THE MOTOR WILL START UP.

WE LEARNED EARLIER THAT THE SCR WILL STAY ON AS LONG AS THE CURRENT THROUGH IT IS MAINTAINED.

THIS BASIC CIRCUIT IS NOT ACCEPTABLE AS A TRIGGERING CIRCUIT BECAUSE THERE IS NO WAY TO TURN THE MOTOR OFF.

LOOK AT VISUAL NUMBER 2

LOOK AT VISUAL NUMBER 3

WHEN THE SCR IS IN ITS "OFF" STATE, THE VOLTAGE WHICH EXISTS ACROSS THE ANODE AND GATE IS EQUAL TO THE LINE VOLTAGE. IN THIS CASE IT IS 48 VOLTS.

WHEN THE PUSH BUTTON IS DEPRESSED, THIS LINE VOLTAGE WILL CAUSE AN EXCESSIVE GATE CURRENT TO FLOW. THIS EXCESSIVE GATE CURRENT WILL PERMANENTLY DAMAGE THE SCR.

LOOK AT VISUAL NUMBER 4

IN ORDER TO PREVENT EXCESSIVE GATE CURRENT A RESISTOR IS

CONNECTED IN SERIES WITH THE PUSH-BUTTON SWITCH. THIS RESISTOR LIMITS THE GATE CURRENT TO A SAFE VALUE.

THE SIZE OF THE RESISTOR IS VERY IMPORTANT. IF IT IS TOO LARGE THERE WILL NOT BE ENOUGH GATE CURRENT TO TRIGGER THE SCR. IF IT IS TOO SMALL THERE WILL BE EXCESSIVE GATE CURRENT.

LOOK AT VISUAL NUMBER 5

THE ADDITION OF A POTENTIOMETER INSTEAD OF THE PUSH BUTTON SWITCH PROVIDES AN EASY MEANS OF VARYING THE SCR GATE CURRENT. THIS ALSO PROVIDES A MEANS OF SPEED CONTROL IN AC CIRCUITS.

WHAT HAPPENS IF THIS CIRCUIT IS CONNECTED TO AC POWER INSTEAD OF DC POWER? LET'S SEE!

LOOK AT VISUAL NUMBER 6

IN THIS CIRCUIT THE SWITCH IN THE POWER CIRCUIT HAS BEEN REMOVED AND THE POWER SOURCE CHANGED TO 48 VOLTS AC.

THE SWITCH IS NOT NEEDED IN AN AC CIRCUIT BECAUSE THE CURRENT AND VOLTAGE IS CONSTANTLY CHANGING IN MAGNITUDE AND IN DIRECTION. EACH TIME THE ALTERNATING CURRENT CHANGES DIRECTION, THE SCR TURNS "OFF" AUTOMATICALLY. THE SWITCH IS NOT NEEDED!

THE SCR BLOCKS THE NEGATIVE HALF OF EACH AC CYCLE WHICH MEANS THE MOTOR CURRENT IS IN ONE DIRECTION, OR DC.

IF THE POTENTIOMETER IS SET AT ITS MINIMUM RESISTANCE SETTING, THE SMALL AMOUNT OF VOLTAGE CREATED WHEN THE POSITIVE AC CYCLE BEGINS WILL BE ENOUGH TO CAUSE THE SCR TO FIRE. THE SCR WILL REMAIN "ON" FOR THE REMAINING PORTION OF THE POSITIVE HALF CYCLE.

INCREASING THE RESISTANCE OF THE POTENTIOMETER MEANS THAT MORE VOLTAGE IS NEEDED TO TURN "ON" THE SCR. WE CAN GET THIS VOLTAGE AT A LATER TIME IN THE POSITIVE HALF OF THE AC CYCLE. ONCE THE VOLTAGE REACHES THIS POINT THE SCR WILL FIRE AND CONDUCT CURRENT FOR THE REST OF THE POSITIVE HALF CYCLE.

IF THE RESISTANCE OF THE POTENTIOMETER IS HIGH ENOUGH, THE SCR WILL NOT FIRE AT ALL.

RESISTANCE TRIGGERING CAN ONLY CONTROL SCR FIRING DURING THE FIRST HALF OF THE POSITIVE AC CYLCE. THIS IS CALLED HALF-WAVE CONTROL.

ALTHOUGH THE SWITCH IS ELIMINATED FROM THE POWER CIRCUIT A DIODE MUST BE ADDED WITH AC.

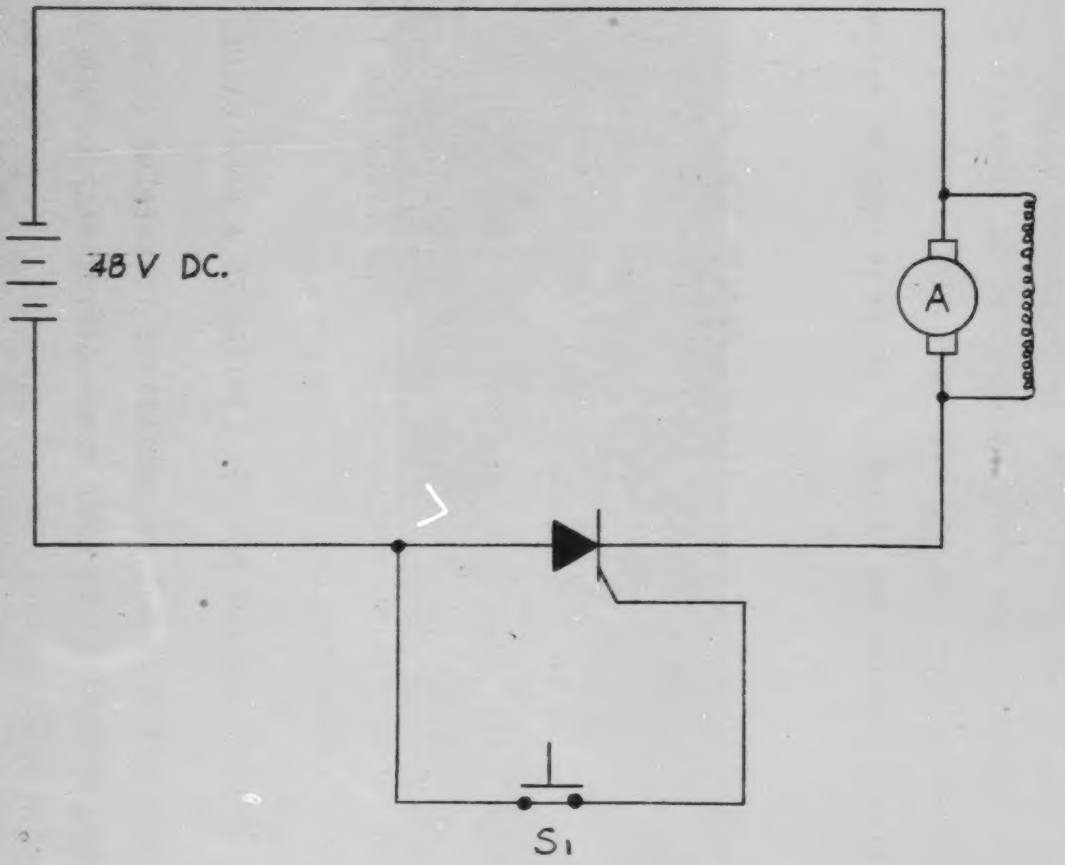
LOOK AT VISUAL NUMBER 7

WHEN CONNECTED TO AC, THE SCR GATE WILL BECOME ENERGIZED AT A NEGATIVE POTENTIAL WHICH WOULD CAUSE IT TO BE DAMAGED. TO PREVENT THIS TYPE OF DAMAGE, A DIODE IS CONNECTED IN SERIES WITH THE GATE AND TRIGGERING CIRCUIT.

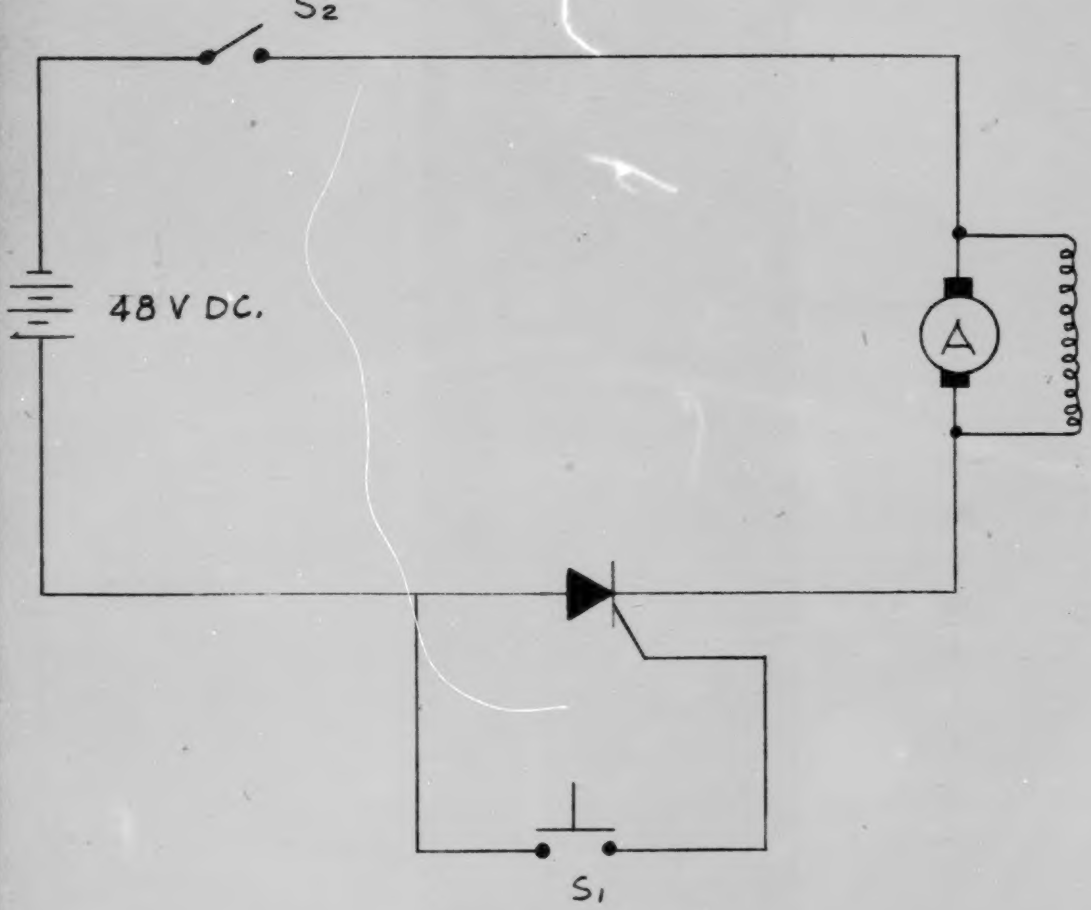
SUMMARY

1. RESISTANCE TRIGGERING IS THE SIMPLEST METHOD OF FIRING AN SCR.
2. WHEN AN SCR IS TRIGGERED, IT WILL REMAIN "ON" AS LONG AS CURRENT IS FLOWING THROUGH IT.
3. WHEN CONNECTED TO AC, IT WILL ONLY CONDUCT DURING HALF OF THE AC CYCLE.
4. ONCE TRIGGERED IN AN AC CIRCUIT, THE SCR WILL REMAIN ON DURING THE REMAINING PORTION OF THE HALF CYCLE AND THEN TURN OFF AUTOMATICALLY.
5. THE SCR GATE CURRENT MUST BE LIMITED TO A SAFE VALUE.
6. THE MAIN DISADVANTAGE OF RESISTANCE TRIGGERING IS THAT ITS CONTROL IS LIMITED TO ONLY THE POSITIVE HALF OF THE AC CYCLE.

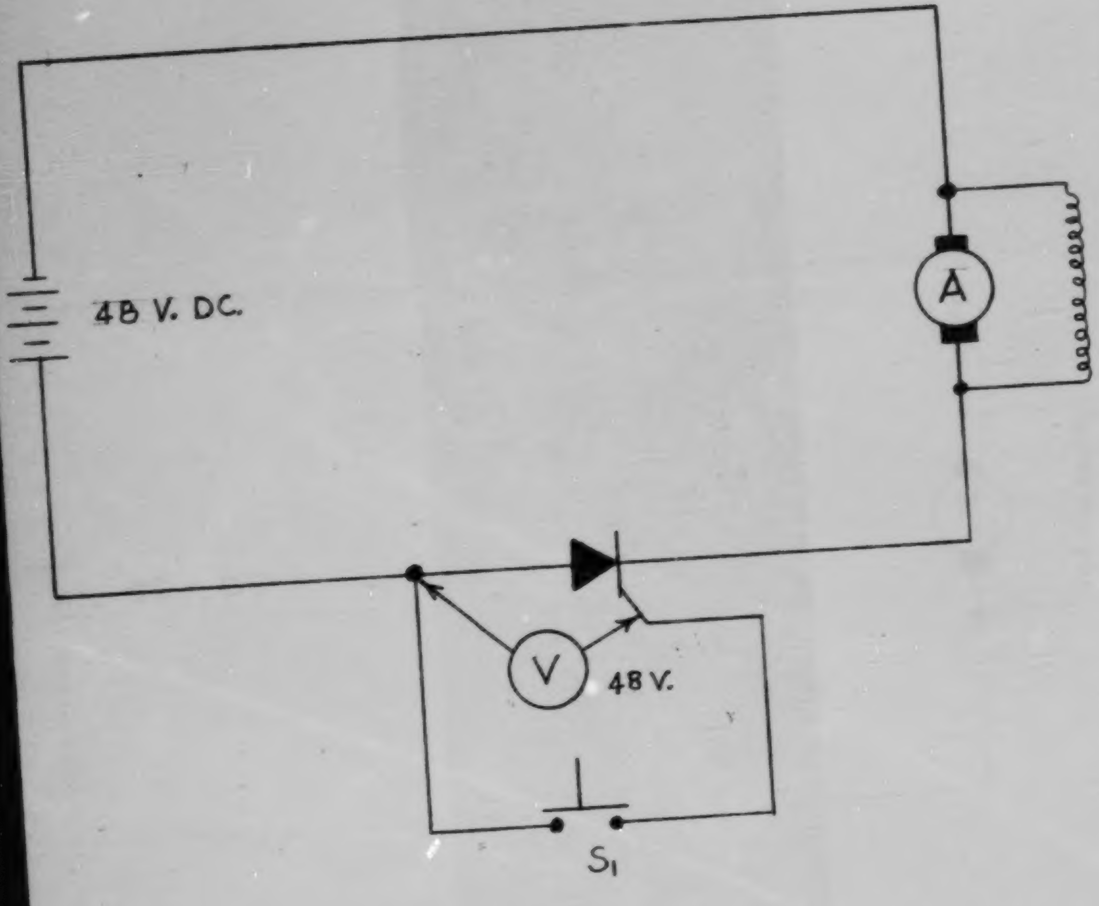
GET EXPERIMENT #1, "RESISTANCE TRIGGERING." COMPLETE THE EXPERIMENT USING EQUIPMENT AND COMPONENTS PROVIDED BY THE INSTRUCTOR.



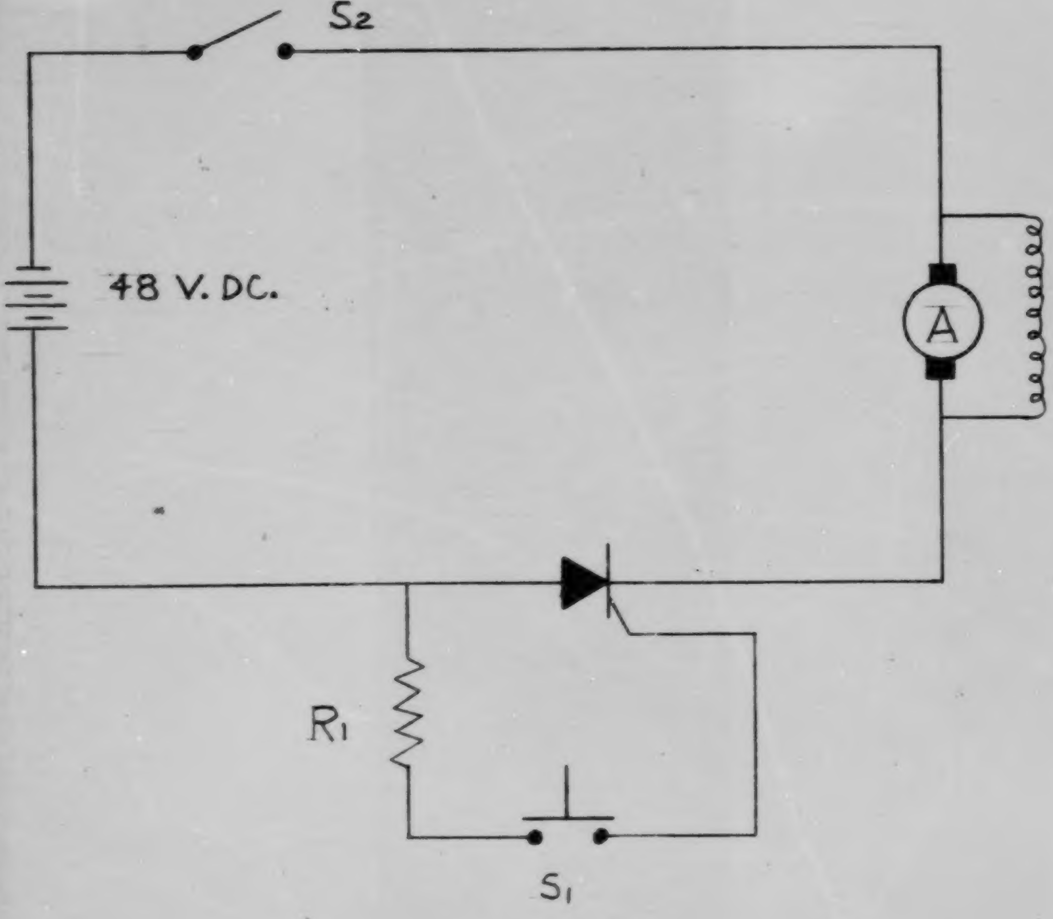
VISUAL NO. 1


S2
48 V DC.
A
S1

VISUAL NO. 2

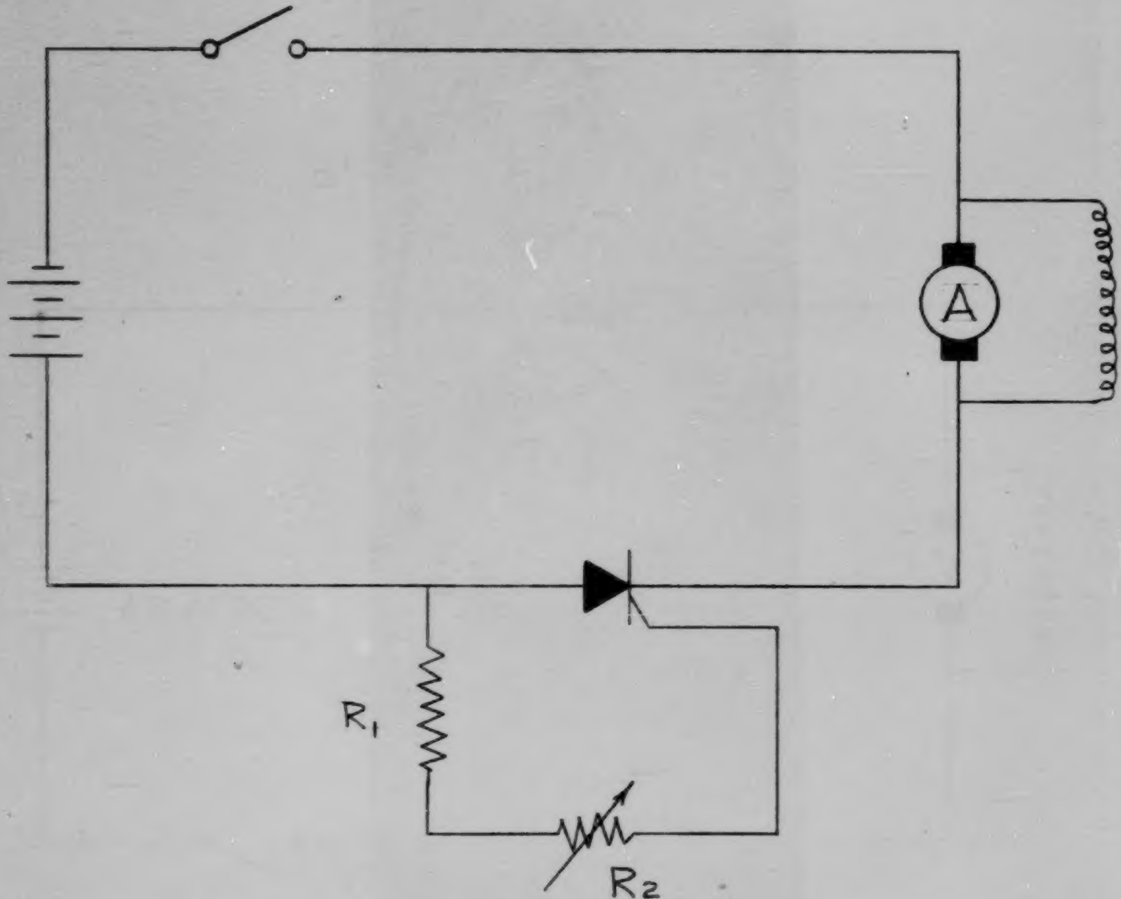

48 V. DC.
A
V
48 V.
S₁

VISUAL NO. 3

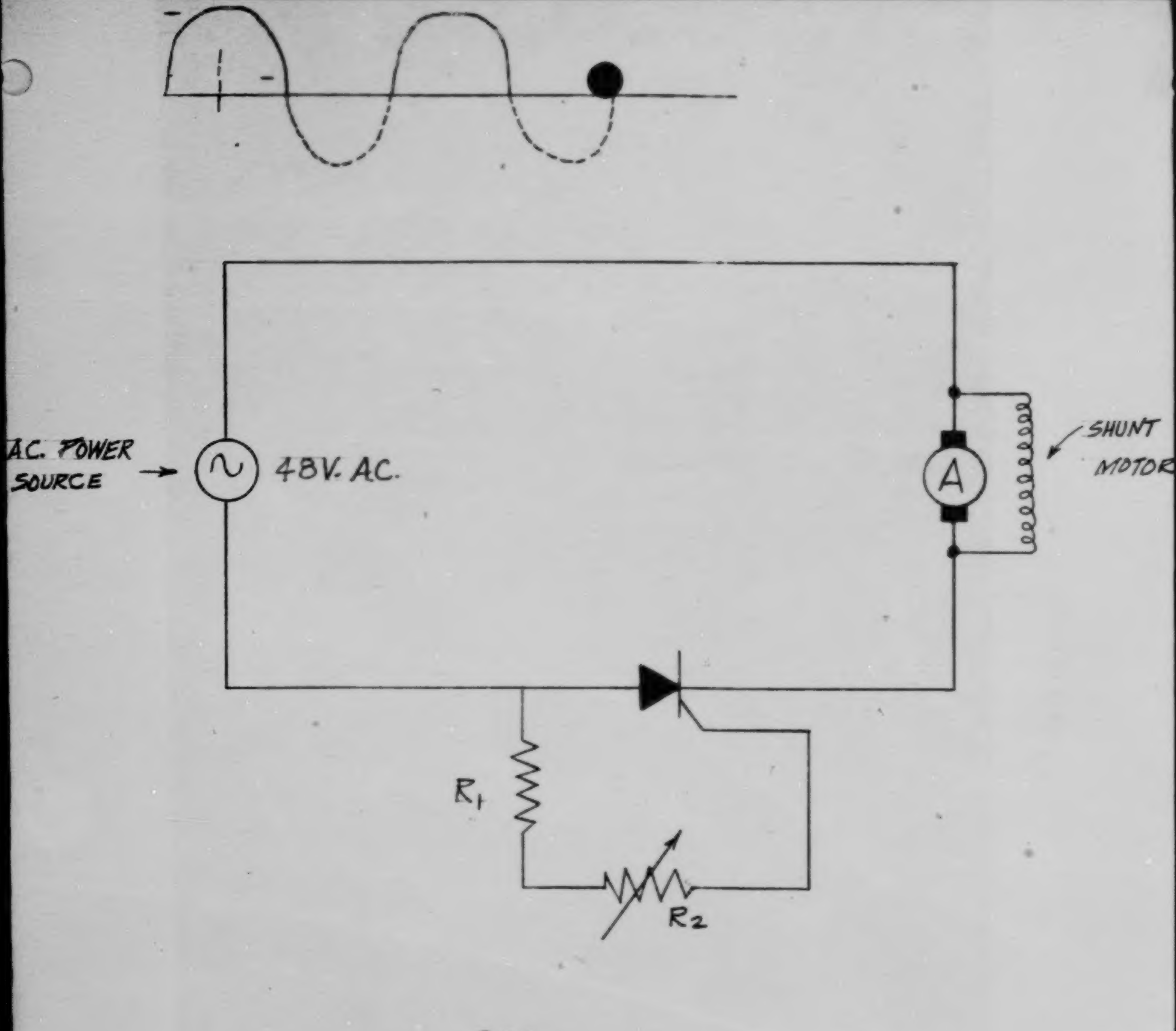

S2
48 V. DC.
A
R1
S1

226

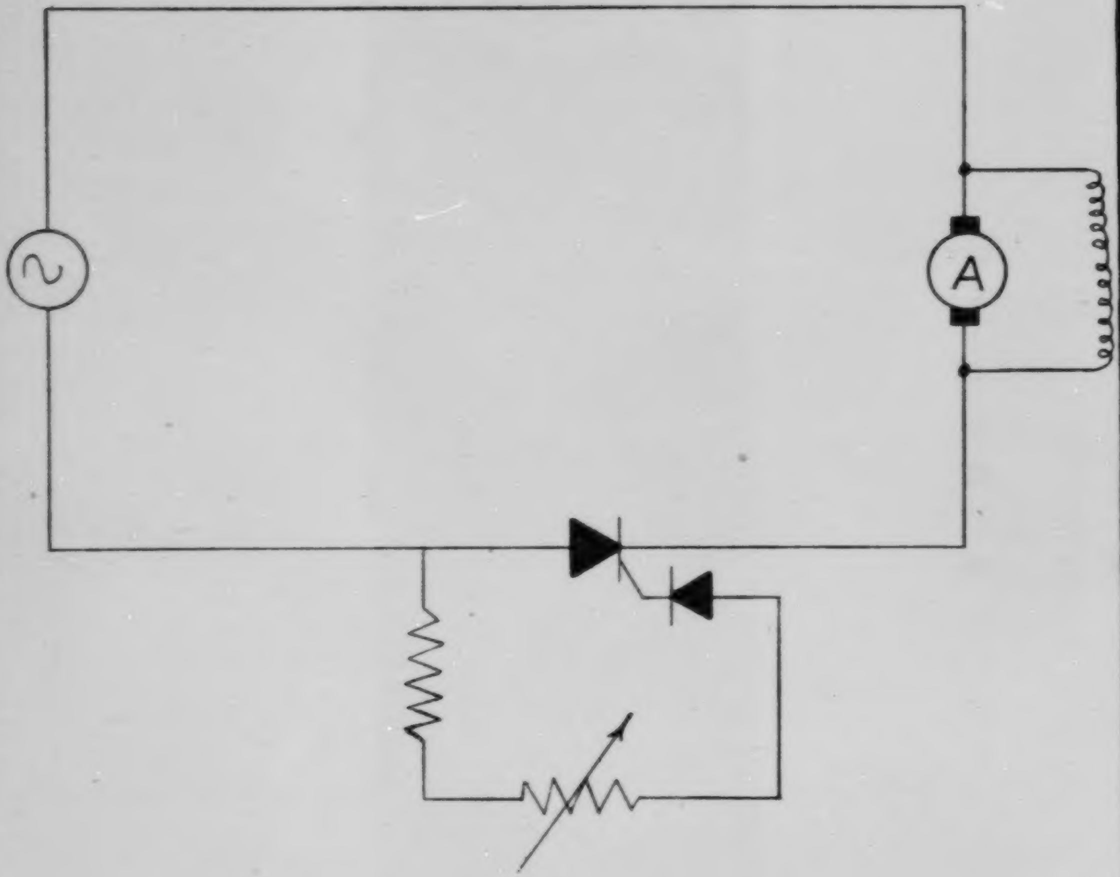
VISUAL NO. 4



VISUAL NO. 5


-
-
AC. POWER SOURCE
48V. AC.
A
SHUNT MOTOR
R1
R2

VISUAL NO. 6



VI[illegible]AL NO. 7

STUDENT HANDOUT #2

RC TRIGGERING

UNIT 07: TRIGGERING CIRCUITS

BE SURE YOU HAVE VISUALS 8 AND 9 BEFORE READING THIS.

RESISTIVE-CAPACITIVE (RC) TRIGGERING CIRCUITS PROVIDE A POSITIVE POTENTIAL AT THE GATE OF THE SCR IN ORDER FOR IT TO FIRE. THEY DO THIS BY CHARGING AND DISCHARGING A CAPACITOR THROUGH A RESISTOR.

IN AN RC CIRCUIT TIMING IS PROVIDED SINCE IT TAKES A DEFINITE TIME FOR A CAPACITOR TO CHARGE OR DISCHARGE. THE TIME REQUIRED TO CHARGE OR DISCHARGE THE CAPACITOR WILL DEPEND ON THE SIZE OF THE CAPACITOR AND THE RESISTOR. A CAPACITOR WILL TAKE LONGER TO CHARGE OR DISCHARGE THROUGH A HIGH RESISTANCE THAN IT WOULD THROUGH A LOW RESISTANCE.

A SIMPLE RC TRIGGERING CIRCUIT WOULD LOOK LIKE THE ONE IN VISUAL 8.

LOOK AT VISUAL NUMBER 8

THE RC TRIGGERING CIRCUIT HAS A CAPACITOR, A VARIABLE RESISTOR (POTENTIOMETER), AND A DIODE.

THE CAPACITOR IS CONNECTED IN SERIES WITH THE POTENTIOMETER. BY DOING THIS THE CHARGING TIME FOR THE CAPACITOR IS CONTROLLED BY THE RESISTOR. NOW, LET'S SEE HOW IT OPERATES.

AT THE BEGINNING OF THE POSITIVE HALF OF THE AC CYCLE CURRENT FLOWS FROM LINE 1 THROUGH THE CAPACITOR. FROM THE CAPACITOR CURRENT FLOWS THROUGH THE POTENTIOMETER AND BACK TO THE ANODE OF THE SCR. AS THE AC VOLTAGE BUILDS UP TO ITS PEAK THE CHARGE OF THE CAPACITOR WILL ALSO BUILD UP.

THE VALUE OF THE RC TRIGGERING CIRCUIT LIES IN THE DIFFERENCE BETWEEN THE CHARGE OF THE CAPACITOR AND THE VOLTAGE AT ANY GIVEN INSTANT IN TIME.

IF THE RESISTOR IS SET AT A LOW VALUE, THE CAPACITOR WILL CHARGE AND DISCHARGE QUICKLY AS THE VOLTAGE INCREASES FROM ZERO TO PEAK VOLTAGE AND DECREASES BACK TO ZERO.

IF THE RESISTOR IS SET AT A HIGH VALUE, THE CAPACITOR CANNOT CHARGE OR DISCHARGE AS FAST AS THE VOLTAGE CHANGES. UNDER THIS CONDITION MORE OF THE TRIGGER CIRCUIT CURRENT IS DIVERTED THROUGH THE SCR GATE. THIS WILL CAUSE THE SCR TO FIRE. NOW LET'S LOOK AT THE SAME CIRCUIT FROM ANOTHER POINT OF VIEW.

DURING THE NEGATIVE HALF OF THE PREVIOUS AC CYCLE THE CAPACITOR

WAS CHARGED IN THE REVERSE DIRECTION. THAT IS, THE PLATE THAT IS CONNECTED TO THE CATHODE OF THE SCR IS POSITIVE AND THE CAPACITOR PLATE WHICH IS CONNECTED TO THE SCR GATE IS NEGATIVE.

AS THE NEXT POSITIVE HALF CYCLE BEGINS THE CAPACITOR'S CHARGE MUST BE REVERSED. THIS MEANS THAT FIRST THE CAPACITOR MUST BE DISCHARGED AND THEN RE-CHARGED IN THE OPPOSITE DIRECTION. WHEN CHARGED IN THIS DIRECTION THE CAPACITOR PLATE WHICH IS CONNECTED TO THE SCR GATE IS POSITIVE. REMEMBER, ONE OF THE CONDITIONS NECESSARY TO FIRE THE SCR IS THAT THE GATE MUST BE POSITIVE.

RECALL, THAT IN STUDYING RESISTANCE TRIGGERING, THE MAIN DISADVANTAGE WAS THAT THE SCR COULD ONLY BE CONTROLLED DURING THE FIRST HALF OF EACH POSITIVE HALF CYCLE. NOT SO WITH RC TRIGGERING! IN RC TRIGGERING, THE SCR CAN BE CONTROLLED DURING THE ENTIRE POSITIVE HALF CYCLE. HOW?

A CAPACITOR IS A DEVICE WHICH CAN STORE ELECTRICAL ENERGY. IN THE RC TRIGGERING CIRCUIT, THE CAPACITOR WILL CHARGE UP DURING THE FIRST HALF OF THE POSITIVE CYCLE. THEN, WHEN THE VOLTAGE STARTS DECREASING TOWARD ZERO, THE CAPACITOR RETURNS ITS STORED ENERGY BACK TO THE CIRCUIT. THIS ALLOWS THE VOLTAGE ACROSS THE SCR GATE TO BE HIGH ENOUGH TO FIRE IT EVEN THOUGH THE VOLTAGE IS TOO LOW TO FIRE THE SCR.

LOOK AT VISUAL NUMBER 9

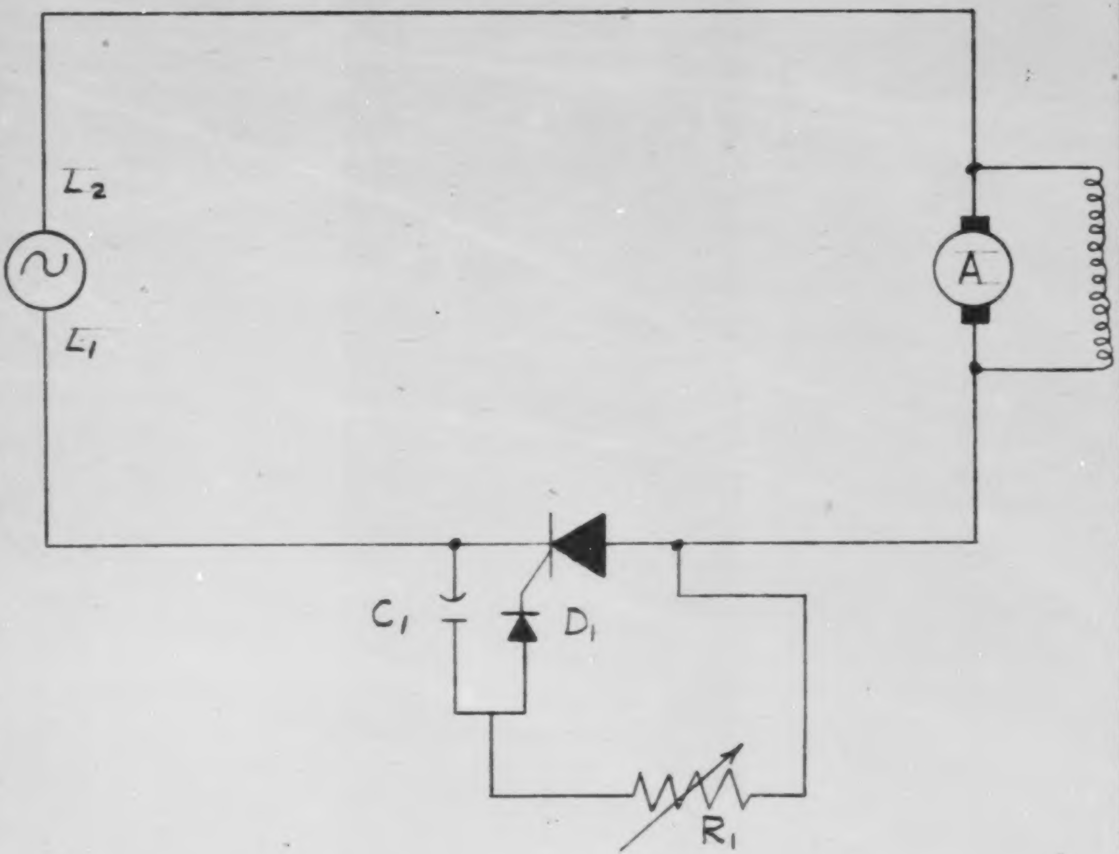
IN THIS CIRCUIT A DIODE HAS BEEN ADDED IN PARALLEL WITH THE POTENTIOMETER. DURING THE NEGATIVE HALF OF EACH AC CYCLE THE CAPACITOR WILL CHARGE TO A MAXIMUM REVERSE VOLTAGE. IN THIS CASE THE POTENTIOMETER ONLY CONTROLS THE CAPACITOR CURRENT IN ONE DIRECTION. SINCE THE CAPACITOR IS FULLY CHARGED AT THE BEGINNING OF EACH POSITIVE CYCLE THE TIMING RANGE IS EXTENDED.

IN RC TRIGGERING, LIKE RESISTANCE TRIGGERING, THE SCR FUNCTIONS AS BOTH A RECTIFYING DEVICE AND AS A CONTACTOR.

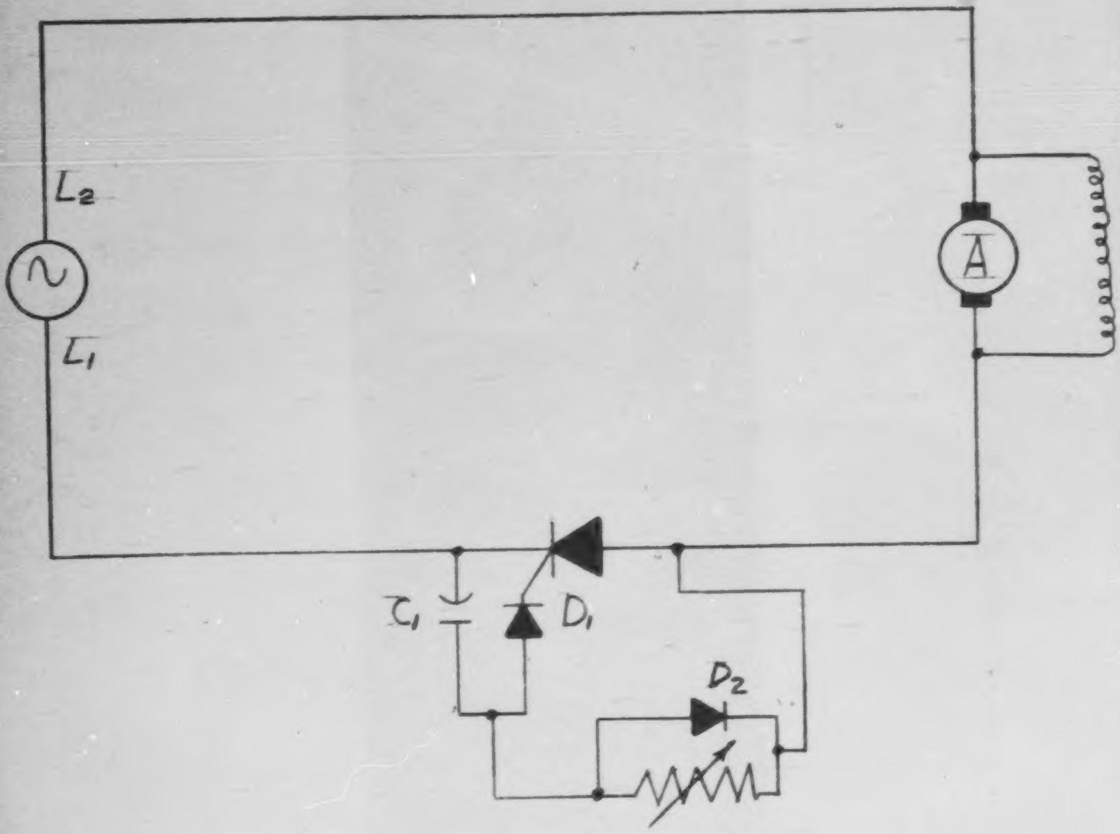
SUMMARY

1. RC TRIGGERING PROVIDES FULL HALF-WAVE CONTROL.
2. TIMING IS PROVIDED BY CHARGING AND DISCHARGING A CAPACITOR THROUGH A RESISTOR.
3. THE CAPACITOR PROVIDES A POSITIVE POTENTIAL AT THE SCR GATE.
4. THE SCR IS USED AS A RECTIFIER.
5. THE SCR SERVES AS A CONTACTOR OR SWITCH TO TURN THE MOTOR ON OR OFF.

COMPLETE EXPERIMENT #2, "RC TRIGGERING." THE INSTRUCTOR WILL GIVE YOU THE MATERIALS.


L2
L1
A
C1
D1
R1

VISUAL NO. 8


L₂
L₁
A
C₁
D₁
D₂

VISUAL NO. 9

STUDENT HANDOUT #3
UJT TRIGGERING

UNIT 07: TRIGGERING CIRCUITS.

BE SURE YOU HAVE VISUAL 10 BEFORE READING THIS. YOU HAVE STUDIED THE RESISTANCE AND RC METHODS OF TRIGGERING AN SCR. NOW LET'S LOOK AT ANOTHER METHOD.

THE UJT METHOD OF TRIGGERING AN SCR USES UNIJUNCTION TRANSISTORS, RESISTORS, AND CAPACITORS TO PROVIDE A PULSE TO THE SCR GATE.

LOOK AT VISUAL NUMBER 10

CURRENT FLOWS THROUGH THE CAPACITOR, THROUGH THE POTENTIOMETER, THROUGH THE PROTECTIVE RESISTOR (R3) AND TO THE ANODE OF THE SCR. THIS CURRENT CHARGES THE CAPACITOR. WHEN THE CAPACITOR'S CHARGE BECOMES HIGH ENOUGH THE POSITIVE PLATE OF THE CAPACITOR CAUSES THE EMITTER OF THE UJT TO BE POSITIVE. THIS "TURNS ON" THE UJT. THIS ALLOWS IT TO CONDUCT CURRENT FROM ITS BASE 1 TO ITS BASE 2. CURRENT NOW FLOWS FROM THE GATE OF THE SCR THROUGH THE TRANSISTOR, THROUGH THE PROTECTIVE RESISTOR (R3) AND THE ANODE OF THE SCR. AT THE SAME TIME, THE CAPACITOR DISCHARGES THROUGH (R2), THE TRANSISTOR'S BASE 1, AND EMITTER, AND BACK TO THE OTHER PLATE OF THE CAPACITOR. ALL OF THIS HAPPENS IN AN INSTANT OF TIME.

REMEMBER THAT THE AMOUNT OF CURRENT THAT WILL PASS THROUGH BASE 1 AND BASE 2 OF THE TRANSISTOR IS DIRECTLY RELATED TO THE AMOUNT OF CURRENT PASSING THROUGH ITS BASE 1 AND EMITTER. IF A LARGE AMOUNT OF CURRENT FLOWS THROUGH THE EMITTER, THEN A LARGE AMOUNT WILL FLOW THROUGH ITS BASE 1 AND BASE 2.

YOU KNOW THAT A CAPACITOR GETS MOST OF ITS CHARGE WHEN IT IS FIRST CONNECTED TO A POWER SOURCE. THIS MEANS THAT WHEN THE CAPACITOR DISCHARGES THROUGH BASE 1 AND THE EMITTER OF THE UJT THERE IS A LARGE INITIAL CURRENT FLOW. AS THE CAPACITOR CONTINUES TO DISCHARGE, THE CURRENT FLOW DECREASES AT A STEADY RATE.

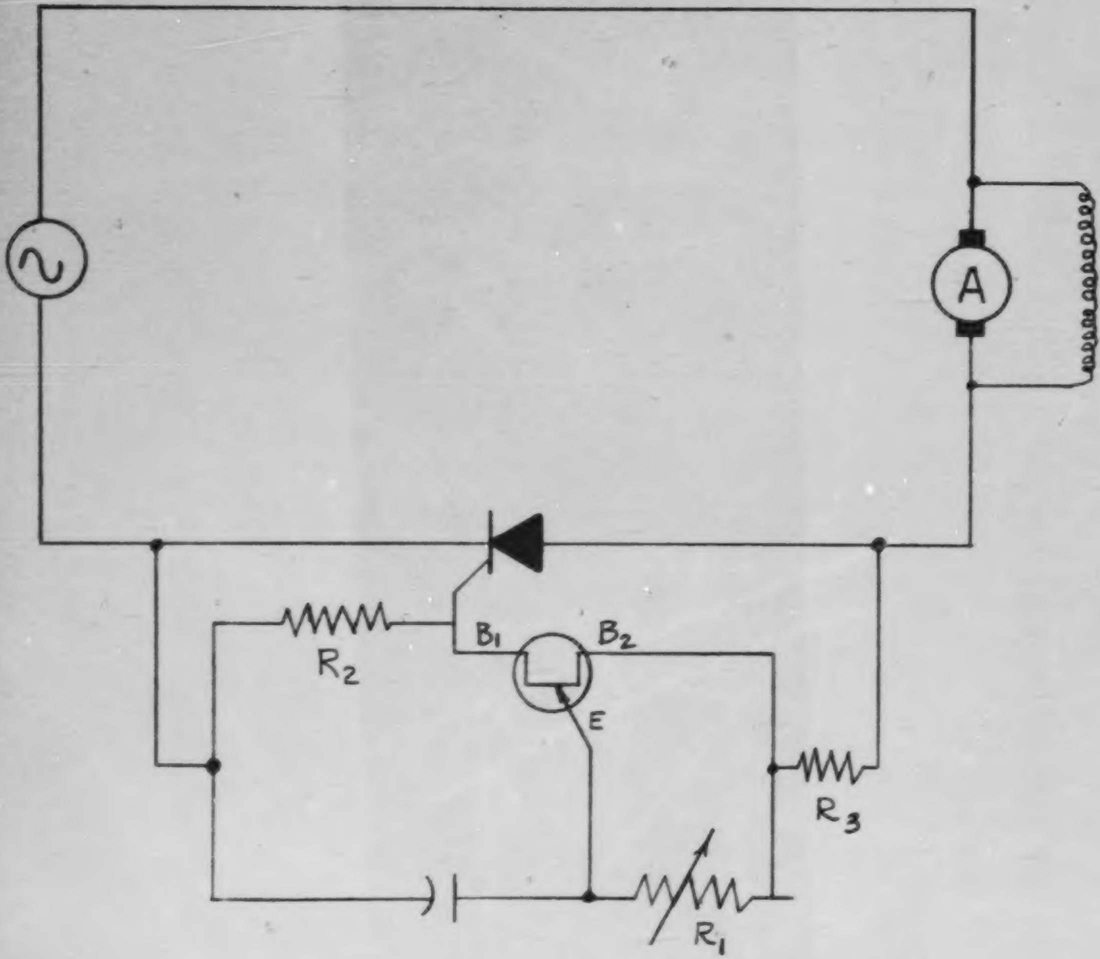
IF THE BASE 1 TO EMITTER CURRENT FLOW TELLS US THE AMOUNT OF CURRENT FLOW THROUGH BASE 1 AND BASE 2 OF THE TRANSISTOR, THEN THE GATE CURRENT OF THE SCR MUST BE AN INITIAL SURGE WHICH THEN DECREASES STEADILY TO ZERO. THIS IS COMMONLY REFERRED TO AS A PULSE.

WHEN AC CHANGES DIRECTION, THE CAPACITOR CHARGES IN THE REVERSE DIRECTION. THE CIRCUIT IS SET FOR THE NEXT POSITIVE ALTERATION OF THE AC SUPPLY.

THE SCR ONLY RECEIVES A GATE PULSE FOR A BRIEF INSTANT. ONCE TRIGGERED, THE SCR STAYS "ON" FOR THE REMAINING POSITIVE HALF OF THE AC CYCLE. THE POTENTIOMETER CONTROLS THE CHARGING RATE

OF THE CAPACITOR AND NOT THE RATE AT WHICH IT DISCHARGES. THE UJT CONTROLS THE AMOUNT OF GATE CURRENT.

GET EXPERIMENT 3, "UJT TRIGGERING." YOUR INSTRUCTOR WILL GIVE YOU THE THINGS YOU NEED TO COMPLETE IT.


A
B1
B2
E
R2
R3
R1

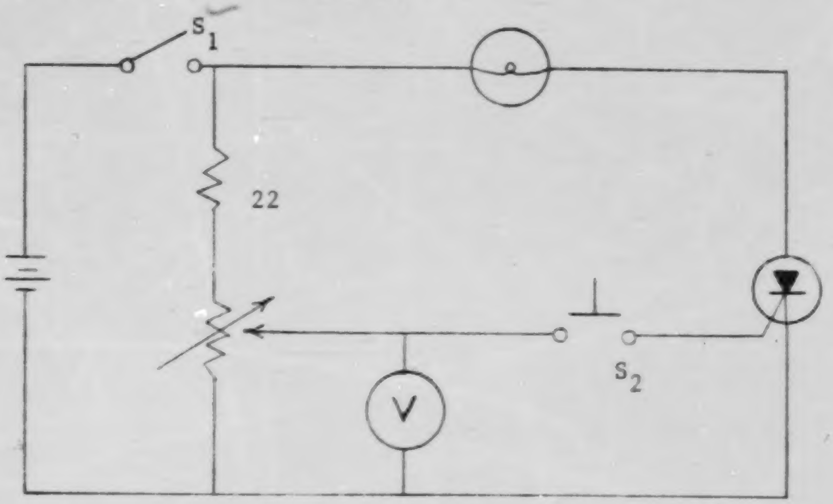
VISUAL NO. 10

EXPERIMENT #1
RESISTANCE TRIGGERING

UNIT 07: TRIGGERING CIRCUITS

DO THE FOLLOWING STEPS:

1. GET THE CIRCUIT BELOW FROM THE INSTRUCTOR.



1. TURN SWITCH NO. 1. WHAT HAPPENS TO THE LAMP?
   WHY?

2. ADJUST THE POTENTIOMETER UNTIL 1 VOLT IS APPLIED TO THE GATE-CATHODE OF THE SCR.
   A. WHAT HAPPENS WITH PUSH-BUTTON SWITCH S_2 IN THE "CLOSED" POSITION? WHY DOES THIS HAPPEN?

B. WHAT HAPPENS AFTER YOU RELEASE SWITCH S_2? WHY DOES THIS HAPPEN?

C. WITH S_2 SWITCH CLOSED, VARY THE SETTING OF THE POTENTIOMETER. WHAT HAPPENS TO THE LAMP AND WHY?

3. REPLACE THE 6-VOLT BATTERY WITH A 6-VOLT AC POWER SOURCE.
   A. REPEAT THE PROCEDURES YOU FOLLOWED WHEN YOU USED THE BATTERY.
   B. ARE THERE ANY DIFFERENCES IN WHAT HAPPENS?

4. WITH THE SCR TRIGGERED INTO CONDUCTION, WHAT HAPPENS WHEN RESISTANCE IS DECREASED IN THE DC CIRCUIT? WHAT HAPPENS IN THE AC CIRCUIT?

5. WITH THE SCR TRIGGERED INTO CONDUCTION, WHAT HAPPENS WHEN RESISTANCE IS INCREASED IN THE DC CIRCUIT? WHAT HAPPENS IN THE AC CIRCUIT?

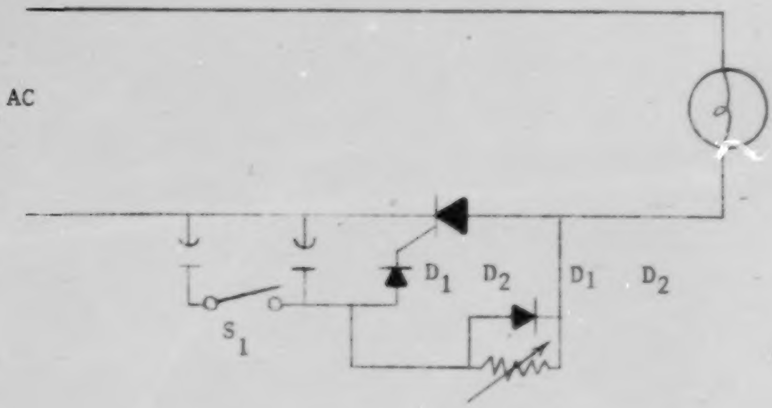
6. WHAT HAPPENS IF THE TRIGGERING CIRCUIT IS DISCONNECTED AFTER THE SCR HAS BEEN TRIGGERED INTO CONDUCTION WITH A DC POWER SOURCE? WHAT HAPPENS WITH AN AC POWER SOURCE?

EXPERIMENT #2
RC TRIGGERING

Unit 07: Triggering Circuits

Do the following steps:

1. Get the circuit below from the instructor.



2. Turn switch S_1 off.
3. Connect the circuit to a 6-volt AC power supply.
4. Vary the potentiometer from zero resistance to maximum resistance. What happens to the lamp?
5. Connect a voltmeter and read the gate-cathode voltage. What is the reading?
6. How does this voltage differ from the reading you would obtain from a resistance triggering circuit?

7. Turn potentiometer to minimum resistance.

8. Close switch S_1. This connects the two capacitors in parallel which increases capacitance to 155 MFD. What happens to the lamp?

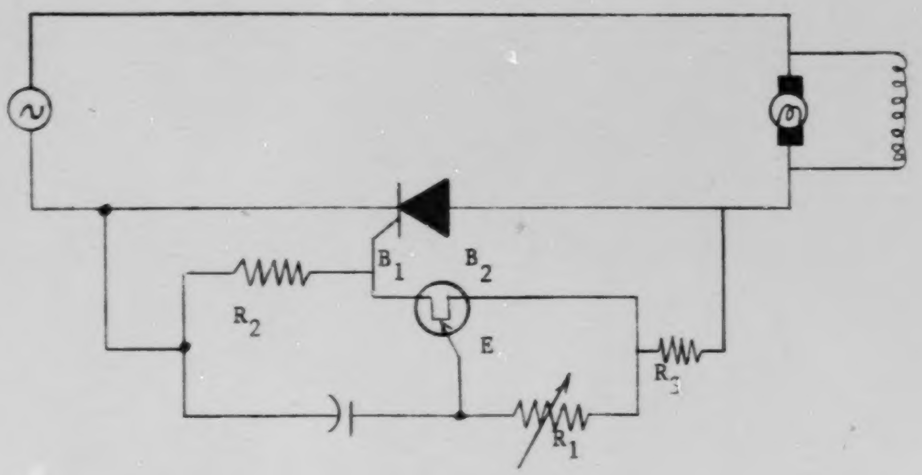
EXPERIMENT #3

UJT TRIGGERING

UNIT: 07 TRIGGERING CIRCUITS

DO THE FOLLOWING STEPS:

1. GET THE CIRCUIT BELOW FROM THE INSTRUCTOR.



2. WITH THE CIRCUIT ENERGIZED, VARY THE POTENTIOMETER. WHAT HAPPENS TO THE LIGHT?

3. WITH A VOLTMETER, MEASURE THE GATE-CATHODE VOLTAGE AT A LOW, MEDIUM, AND HIGH SETTING OF THE POTENTIOMETER. RECORD YOUR MEASUREMENTS HERE.

_______________ _______________ _______________

4. WHAT IS THE PURPOSE OF THE UJT IN THIS CIRCUIT?

5. HOW DO WE GET TIMING WITH THE UJT CIRCUIT?

6. HOW DOES UJT TRIGGERING DIFFER FROM RESISTANCE AND RC TRIGGERING?

7. LIST TWO ADVANTAGES OF UJT TRIGGERING.

STUDENT EXAMINATION #1

UNIT: 07 TRIGGERING CIRCUIT

1. A CIRCUIT WHICH CONTROLS THE TIME WHICH AN SCR "TURNS ON" AND "TURNS OFF" IS KNOWN AS A:
   A. TRIGGERING OR FIRING CIRCUIT
   B. TURN-ON CIRCUIT
   C. TURN-OFF CIRCUIT
   D. SERIES-PARALLEL CIRCUIT

2. THE ADVANTAGE OF RC TIMING OVER THE SIMPLE RESISTIVE TIMING IS THAT:
   A. RC TIMING AFFORDS FULL HALF-CYCLE CONTROL.
   B. RC TIMING REQUIRES LESS MAINTENANCE.
   C. RC TIMING IS LESS EXPENSIVE.
   D. RC TIMING HAS NO ADVANTAGES OVER RESISTANCE TIMING.

3. IN THE UJT CIRCUIT THE UJT:
   A. SERVES IN PLACE OF A RESISTOR TO CONTROL THE GATE CURRENT.
   B. PREVENTS THE CAPACITOR FROM DISCHARGING THROUGH THE GATE OF THE SCR.
   C. PREVENTS REVERSE CURRENT FROM THE ANODE OF THE SCR.
   D. PREVENTS REVERSE CURRENT FROM THE CATHODE OF THE SCR.

4. AN ELECTRICAL COMPONENT WHICH CAN BE USED TO CONTROL THE CHARGING TIME OF A CAPACITOR IS:
   A. A CAPACITOR
   B. A RESISTOR
   C. AN SCR
   D. A TRANSISTOR

5. INCREASING THE SIZE OF A CAPACITOR IN A TRIGGER CIRCUIT WILL:
   A. REQUIRE MORE TIME FOR IT TO CHARGE.
   B. REQUIRE LESS TIME FOR IT TO CHARGE.
   C. NOT CHANGE THE TIMING.
   D. NONE OF THE ABOVE.
6. A RESISTOR IS CONNECTED IN SERIES WITH THE SCR GATE IN RESISTANCE TRIGGERING TO:
   A. LIMIT GATE CURRENT.
   B. PROVIDE TIMING CONTROL.
   C. ALL OF THE ABOVE.
   D. NONE OF THE ABOVE.
7. WE CAN GET CORRECT POLARITY TO TRIGGER AN SCR BY USING A:
   A. RESISTOR
   B. SWITCH
   C. UJT
8. THE PURPOSE OF TWO DIODES IN AN RC TRIGGER CIRCUIT IS TO:
   A. PREVENT NEGATIVE VOLTAGE ON THE SCR GATE.
   B. PERMIT THE CAPACITOR TO BE CHARGED FASTER IN ONE DIRECTION THAN THE OTHER DIRECTION.
   C. ALL OF THE ABOVE.
   D. NONE OF THE ABOVE.

STUDENT COMPETENCY SHEET #1

UNIT: 08 SCHEMATICS: DC SYMBOLS

COMPETENCY STATEMENT: IDENTIFIES DC COMPONENT SYMBOLS AND EXPLAINS USE OF COMPONENTS

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT DC COMPONENT SYMBOLS AND ON HOW THESE COMPONENTS ARE USED.

CONDITIONS: YOU WILL HAVE 20 MINUTES. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "DC SYMBOLS," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS ON STUDY SHEET #1.
2. GET SOME SMALL CARDS FROM THE INSTRUCTOR. DRAW THE SYMBOLS FOR THE FOLLOWING COMPONENTS ON THE CARDS. PUT JUST ONE SYMBOL ON EACH CARD. PUT THE NAME FOR THE SYMBOL ON THE BACK OF THE CARD.

ON BUTTON
OFF BUTTON
N.O., INSTANT CLOSING MERCURY TUBE
N.O., TIME DELAY TO CLOSE MERCURY TUBE
LIGHT BULB
VOLTMETER
CONTACTOR COIL
CONTACTOR
REVERSING COIL
MOTOR ARMATURE
RESISTOR
STARTING RESISTANCE
SHUNT FIELD WIRE #1
SERIES FIELD WIRE #3
POWER CIRCUIT (LINES)
OPERATING CIRCUIT (LINES)
OVERLOAD RELAY

3. GET ANOTHER STUDENT. GIVE YOUR SMALL CARDS WITH SYMBOLS ON THEM TO THE STUDENT. WHEN YOU ARE SHOWN A CARD, NAME THE SYMBOL.

4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

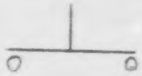
STUDENT HANDOUT #1
DC SYMBOLS

Unit: 08 Schematics: DC Symbols

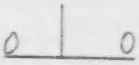
Purpose:

Solid-state circuitry is new to mining. It provides some interesting problems. New symbols must be identified. The purpose and operation of the symbols must be understood. You must have skill in tracing out circuit operation. Being able to do these things will help you solve machine problems. We feel that the best way to help learn new things is to make sure we really know the old things. That is why we are beginning with DC components and symbols.

Push-Button Switches:

A. On Button 

The ON button is a normally open (N.O.) switch. We can identify it by the space between the disc-type contact (shown as an upside-down "T") and the lower contacts. This type of contact is always parallel connected when two or more are used to control the same motor from different stations.

B. Off Button 

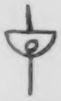
This is the same as the ON button with one difference. The disc is now below the smaller contacts and they are touching. This type contact is always series connected when two or more are used to control the same motor from different stations.

MERCURY TUBES:

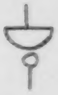
MERCURY TUBES ARE USED IN:

(1) HOLDING CIRCUITS
(2) TIME-DELAY CIRCUITS
(3) OVERLOADS

THE WAY THE SYMBOL IS DRAWN TELLS US HOW IT IS USED:

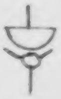
A. NORMALLY CLOSED, INSTANT OPENING. 

THIS TYPE IS USED TO HAVE A COMPLETE CIRCUIT WITH THE ABILITY TO OPEN. THE CIRCUIT MAY NEED TO BE OPENED FOR OVERLOADING CONDITIONS OR SEQUENCING.

B. NORMALLY OPEN, INSTANT CLOSING. 

THE NORMALLY OPEN MERCURY TUBE HAS A SPACE SHOWN BETWEEN THE CONTACT AND THE INVERTED UMBRELLA.

SWITCHES ARE EITHER NORMALLY OPEN OR NORMALLY CLOSED. WHAT DO WE MEAN BY NORMALLY? NORMALLY MEANS WITHOUT INFLUENCE FROM MANUAL, ELECTRICAL, OR MAGNETIC THINGS. IN OTHER WORDS, IN ITS NATURAL RELAXED STATE.

C. NORMALLY OPEN, TIME-DELAY CLOSING. 

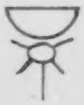
WHEN TWO MORE LINES ARE ADDED ONE MORE FACT IS LEARNED ABOUT THIS MERCURY TUBE SYMBOL:

(1) IT IS STILL NORMALLY OPEN, BUT
(2) IT HAS A TIME DELAY WHEN CLOSING.

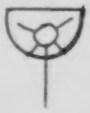
THIS TUBE IS USED WHERE A LITTLE EXTRA TIME IS NEEDED TO DO ANOTHER JOB IN THE CIRCUIT BEFORE WE WANT THE TUBE TO OPERATE. ONE PLACE IS IN SERIES STARTING RESISTANCE. WE WANT A CERTAIN MOTOR TO START IN STEPS. FIRST SLOW THROUGH THE RESISTANCE THEN OUR TIME DELAY MERCURY TUBE CLOSES. THIS OPERATES ANOTHER CONTACTOR TO BYPASS THE RESISTANCE.

D. NORMALLY CLOSED, TIME DELAY TO OPEN

THE TWO ADDITIONAL LINES ON THE SYMBOL SHOW A TIME DELAY IN SOME DIRECTION. WE KNOW THE DIRECTION BY WHETHER OR NOT THE LINES ARE INSIDE OR OUTSIDE THE SYMBOL. LET'S SEE IF YOU CAN GUESS THE NEXT TWO.



SYMBOL (A)



SYMBOL (B)

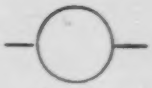
IF YOU SAID THAT SYMBOL (A) IS NORMALLY OPEN, TIME DELAY CLOSING AND OPENING, YOU ARE CORRECT. SYMBOL (B) IS NORMALLY CLOSED, TIME DELAY IN BOTH DIRECTIONS ALSO. DID YOU GUESS CORRECTLY? IF NOT, GO BACK AND REVIEW SYMBOLS "C" AND "D."

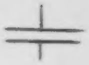
THESE TWO MERCURY TUBES ARE USED WHERE TIME DELAYED OPENING OR CLOSED WOULD BE NEEDED. THIS COULD BE WHERE THERE IS A BRIEF OVERLOAD THAT WOULD NOT BE HARMFUL TO A MOTOR. THEY CAN ALSO BE USED TO KEEP OVERLOAD DEVICES FROM OPERATING TOO SOON.

CONTACTORS AND CONTACTOR COILS

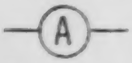
WE WILL DISCUSS THESE TWO COMPONENTS TOGETHER BECAUSE THEY OPERATE TOGETHER.

A. OPERATING COIL AND CONTACTORS

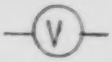

BASIC COIL


CONTACTOR

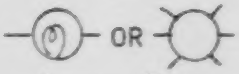
THE SYMBOL SHOWN HERE HAS MANY OTHER USES ON SCHEMATICS BESIDES SHOWING COIL AND CONTACTORS. IT MAY SHOW A VOLTMETER, AN AMMETER, OR A LIGHT BULB. THE IMPORTANT THING IS TO LOOK AT WHAT IS WRITTEN WITHIN THE CIRCLE. LOOK AT THE SYMBOLS BELOW:



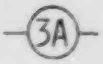
AMMETER



VOLTMETER



LIGHT BULB



OPERATING COIL

THE SYMBOL FOR THE OPERATING COIL TELLS US THAT:

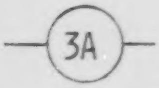
(1) IT IS AN OPERATING COIL

(2) THERE IS A SET OF CONTACTS (3A) SOMEWHERE IN THE SYSTEM THAT IT OPERATES

(3) IF THERE IS A MERCURY TUBE, IT WOULD BE 3A ALSO

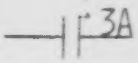
B. CONTACT OPERATING COIL AND CONTACTOR

LOOK AT THESE SYMBOLS.



CONTACTOR COIL

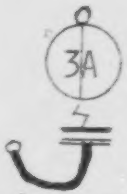
(A)



CONTACTOR

(B)

OR



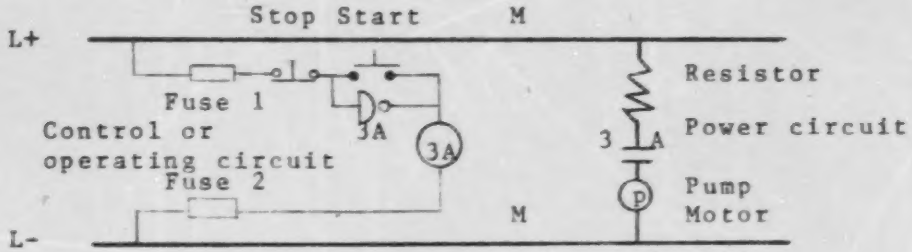
CONTACTOR AND COIL

(C)

THE CONTACTOR COIL DOES NOT HAVE TO BE NEAR THE CONTACTOR ON THE SCHEMATIC. THE TWO ARE TOGETHER ON THE ACTUAL MACHINE. THIS IS SHOWN IN (C) ABOVE.

C. OPERATING AND POWER CIRCUIT SYMBOLS

MOST ELECTRICAL SCHEMATICS WILL HAVE TWO PARTS. LOOK AT THE FIGURE BELOW.

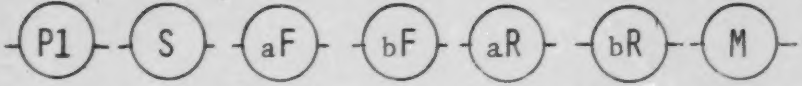

Stop Start
M
L+
Resistor
Fuse 1
Control or
operating circuit
3A
3A
3
A
Power circuit
Fuse 2
Pump
Motor
P
M
L-

THE HEAVY LINES SHOW THE POWER CIRCUIT. THIS IS THE PART OF THE CIRCUIT THAT CONDUCTS THE MOST CURRENT.

THE THIN LINES SHOW THE CONTROL, OR OPERATING CIRCUIT. THIS IS THE PART OF THE CIRCUIT THAT CONDUCTS THE LEAST AMOUNT OF CURRENT.

THE NORMALLY OPEN MERCURY SWITCH (3A), THE OPERATING COIL (3A), AND THE CONTACTOR (3A) PERFORM ONE JOB. THIS IS SHOWN BY THE MARKING "3A." THEY START THE PUMP MOTOR AND KEEP IT RUNNING. ON THE DIAGRAM THEY ARE NOT TOGETHER. ON THE MACHINE ALL THREE ARE MOUNTED TOGETHER.

OPERATING COILS ARE MARKED IN OTHER WAYS TOO. THE MARKINGS SHOW HOW THEY ARE USED IN A CIRCUIT. LOOK AT THE SYMBOLS BELOW.



THERE IS A LOT OF INFORMATION THAT WE CAN GET FROM THE SEVEN SYMBOLS ABOVE. P1 TELLS US THAT

(1) IT IS AN OPERATING COIL

(2) IT OPERATES CONTACTOR P1

(3) THE "P" TELLS US IT IS USED IN A "PARALLEL" CIRCUIT.
THIS MEANS THERE IS A "P2" SOMEWHERE IN THE CIRCUIT.

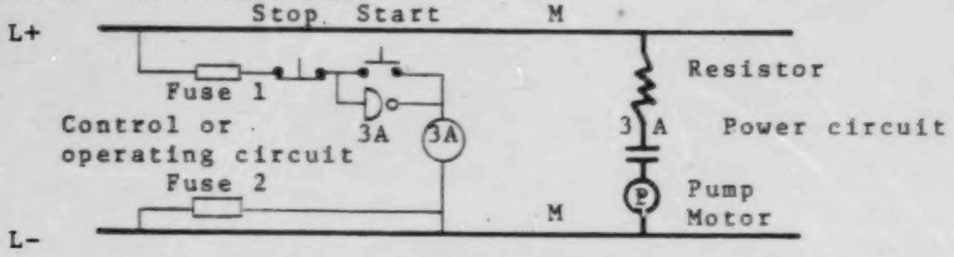
IF P1 OPERATED A MERCURY SWITCH, CAN YOU GUESS HOW IT WOULD BE MARKED? THATS RIGHT, P1. GET THE IDEA?

THE SYMBOL MARKED "S" IS FOR AN OPERATING COIL THAT CLOSES AND OPENS A SET OF SERIES CONTACTORS.

THE SYMBOLS MARKED, aF, bF, aR, AND bR ARE FOR OPERATING COILS THAT ARE FORWARD AND REVERSING. THE SMALL "a" IS FOR A CERTAIN MOTOR. THE "F" TELLS US IT'S A FORWARD CONTACT COIL. THE "R" TELLS US IT'S A REVERSING CONTACTOR COIL.

MOTORS ARE LETTERED a, b, c, d, ETC.

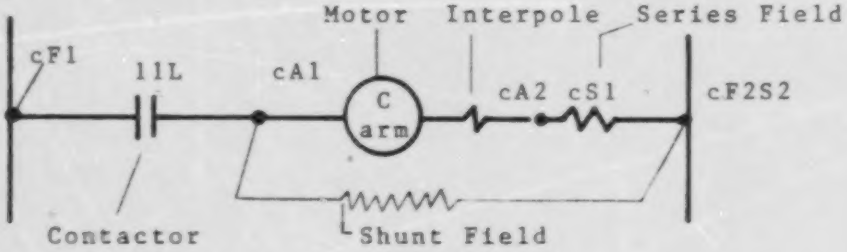
THE "M" CONTACTOR COIL IS FOR THE MAIN CONTACTORS. THESE CONTACTORS CONNECT THE POWER CIRCUIT TO THE SUPPLY CURRENT. LOOK AT THE FIGURE BELOW.


Stop
Start
M
L+
Fuse 1
Control or operating circuit
3A
3A
Fuse 2
L-
M
Resistor
3 A
Power circuit
P
Pump Motor

THE TWO AREAS MARKED "M" SHOW WHERE THE MAIN CONTACTORS WOULD BE PLACED ON THE DIAGRAM. IF MERCURY SWITCHES WERE ALSO PART OF THE CIRCUIT, THEY WOULD BE MARKED M1, M2, ETC.

D. MOTOR SYMBOLS

SCHEMATIC DIAGRAMS GIVE US MUCH INFORMATION ABOUT MOTORS. LOOK AT THE FIGURE BELOW.


Motor
Interpole
Series Field
cF1
11L
cA1
C
arm
cA2
cS1
cF2S2
Contactor
Shunt Field

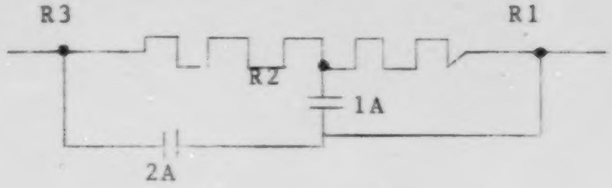
WE SEE WE HAVE A COMPOUND MOTOR. THIS IS SHOWN BY THE SERIES FIELD AND SHUNT FIELD WINDINGS. BY LOOKING AT THE LETTERS cF2 S2 WE KNOW THE CONNECTIONS THAT END AND WHERE THEY COME FROM.

c	F2	S2
WHICH MOTOR	SHUNT FIELD WIRE #2	SERIES FIELD WIRE #2

The number 2 shunt field wire and the series field number 2 wire are connected together at that point. Looking at the letters we see cA2, and, at the other end of the series winding, cS1. These show that the series field and "A" or armature lead of the motor are series connected. The shunt field parallels both of these connections.

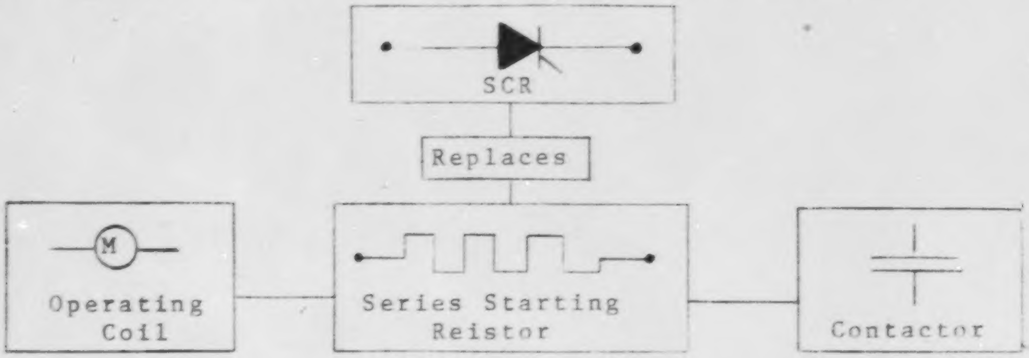
E. Motor Starting Resistors

Look at the figure below.



The figure shows a series starting resistor. Its points of connection are marked R1, R2, and R3. R1 shows the most negative point. Also shown are 1A and 2A contactors. These contactors bypass part of the resistance during the step starting of the motors. There would be contactor coils in the operating circuit marked 1A and 2A to operate these contactors.

F. Comparison of SCR and its Conventional counterparts.



THE SCR REPLACES:

1. SERIES STARTING RESISTORS. WHEN USING AN SCR, THE VOLTAGE APPLIED TO THE MOTOR CAN BE VARIED FROM ZERO TO FULL VOLTAGE. THIS RESULTS IN PRECISE CONTROL OF THE MOTOR'S STARTING CURRENT.

2. CONTACTOR AND COIL. THE SCR CAN OPEN AND CLOSE THE POWER CIRCUIT. WHEN THIS IS DONE WITH THE SCR, WE DO NOT NEED COILS AND CONTACTORS.

SUMMARY

A. THERE ARE TWO PARTS TO EVERY CIRCUIT:
   1. AN OPERATING CIRCUIT:
      A. IS SHOWN BY THE THIN LINES ON A SCHEMATIC.
      B. HAS OPERATING COILS, PUSH BUTTONS OR SWITCHES, AND MERCURY TUBES.
      C. CONDUCTS THE LEAST AMOUNT OF CURRENT.
   2. POWER CIRCUIT:
      A. IS SHOWN BY THE HEAVY LINES ON A SCHEMATIC.
      B. HAS CONTACTORS, RESISTORS, AND MOTORS.
      C. CONDUCTS THE LARGER AMOUNTS OF CURRENT.

B. SYMBOLS:

1. MERCURY SWITCHES OR TUBES:

   A. SHOWN WITH ITS COIL BY HAVING THE SAME LETTER AND NUMBER.

   B. THEY ARE NORMALLY OPEN (N.O.) OR NORMALLY CLOSED (N.C.) SWITCHES.

   C. TIME DELAY ON MERCURY SWITCHES IS SHOWN BY THE SLASHES ON THE SYMBOLS; E.G., \/ OR /\.

   D. IF THE SLASH IS OUTSIDE THE SYMBOL, THE DELAY IS IN **CLOSING.**

   E. IF THE SLASH IS INSIDE THE SYMBOL, THE DELAY IS IN OPENING.

   F. MERCURY TUBES SOMETIMES ARE DELAYED IN BOTH DIRECTIONS.

2. OPERATING COILS:

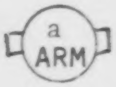
   A. HAVE A SYMBOL MUCH LIKE
      (1) AMMETERS
      (2) VOLTMETERS
      (3) LIGHTBULBS

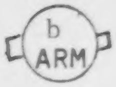
   B. WE CAN IDENTIFY THEM BY READING WHAT IS WRITTEN INSIDE THE SYMBOL. EXAMPLES ARE LIKE THIS.
      (1) -(P1)- PARALLEL OPERATING COIL
      (2) -(S)- SERIES OPERATING COIL
      (3) -(M)- MAIN POWER OPERATING COIL

3. MOTORS:

   A. ARE SHOWN BY A CIRCLE ON SCHEMATICS.

   B. ARE MARKED BY A LOWER-CASE LETTER LIKE THESE EXAMPLES:

      (1) 

      (2) 

4. RESISTORS:

   A. ARE SHOWN BY HEAVY, IRREGULAR LINES ON SCHEMATICS.

   B. HAVE VARIOUS POINTS OF CONNECTION MARKED LIKE THESE EXAMPLES: R1, R2, R3.

   C. R1 IS THE MOST NEGATIVE POINT.

5. CONTACTORS:

   A. HAVE OPERATING COILS TO CLOSE THEM.

   B. ARE SHOWN WITH THEIR COILS AND HAVE THE SAME NUMBERS LIKE THESE EXAMPLES:

      (1) –(M)– ; ⊣⊢ M1; ⊣⊢ M2
      (2) –(P1)– ; ⊣⊢ P1
      (3) –(P2)– ; ⊣⊢ P2

6. SOLID-STATE COMPARISON:

   A. THE SCR REPLACES

      (1) RESISTORS
      (2) CONTACTORS
      (3) OPERATING COILS

STUDY SHEET #1

Unit: 08 Schematics: DC Symbols

Answer these questions.

1. Which type of switch is connected in series? Circle the correct answer.

   ON Button   OFF Button

2. What do we mean when we say a switch is Normally Open?

3. Draw the symbols for four different kinds of mercury tubes. Write the name by each kind.

4. Fill in the symbols to make them show what the name says.

Light Bulb

Coil

Ammeter

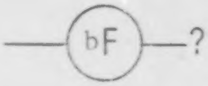
Operating Coil, 4A

5. On a machine, coils and their contractors are located:
   - A. Together.
   - B. In different places.

6. Which part of a circuit carries the least amount of current? Circle the correct letter.

   A. Power circuit.

   B. Control circuit.

7. What does this symbol show ?

8. What does this symbol show c F_2 S_2?

9. If you saw R-1, R-2, R-3, and R-4 on a schematic, which would be the most negative point? Circle the correct answer.

   R-1   R-2   R-3   R-4

10. Name three DC components the SCR can replace.

STUDENT EXAMINATION #1

UNIT: 08 SCHEMATICS: DC SYMBOLS

1. NAME THREE CONVENTIONAL COMPONENTS THAT AN SCR REPLACES.

2. DRAW THE SYMBOLS FOR THE COMPONENTS LISTED. MARK THE SYMBOLS TO SHOW THAT THEY ALL WORK TOGETHER TO PERFORM ONE JOB.

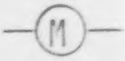
   A. PARALLELING OPERATING COIL

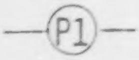
   B. A CONTACTOR

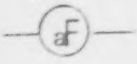
   C. A NORMALLY OPEN, INSTANT CLOSING, MERCURY SWITCH.

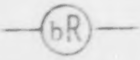
3. DRAW THE SYMBOL FOR A NORMALLY OPEN, TIME DELAY CLOSING MERCURY SWITCH.

4. WHICH OF THE SYMBOLS BELOW SHOWS THE FORWARD CONTROL COIL OF A MOTOR?

   A. 

   B. 

   C. 

   D. 

5. WHICH POINT ON A SERIES STARTING RESISTOR IS THE MOST NEGATIVE POINT?

6. MAKE TWO LISTS, ONE FOR OPERATING CIRCUIT AND ONE FOR POWER CIRCUIT. NAME THREE COMPONENTS IN EACH.

7. DRAW THE SYMBOL FOR EACH OF THE ITEMS THAT YOU HAVE NAMED IN THE LISTS ABOVE.

STUDENT COMPETENCY SHEET #2

UNIT: 08 SCHEMATICS: DC CIRCUIT TRACING

COMPETENCY STATEMENT: TRACES CURRENT FLOW ON A DC SCHEMATIC AND EXPLAINS OPERATION

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. TRACE WITH A PENCIL THE CURRENT FLOW ON A DC SCHEMATIC.
2. EXPLAIN TO THE INSTRUCTOR THE OPERATION OF THE CIRCUITS YOU TRACE.

CONDITIONS: YOU HAVE A DC SCHEMATIC. YOU MAY NOT USE REFERENCES. YOU HAVE 20 MINUTES TO DO THIS.

STANDARDS: ALL YOUR TRACING AND EXPLAINING MUST BE CORRECT. THIS MEANS THAT THE CIRCUITS REALLY WOULD WORK LIKE YOU SAY.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1 "DC SYSTEM COMPONENTS," FROM THE INSTRUCTOR. READ IT.

2. GET STUDENT HANDOUT #2, "DC SCHEMATIC TRACING," FROM THE INSTRUCTOR. READ IT.

3. GET A CLEAN COPY OF THE DC SCHEMATIC. TRACE WHAT HAPPENS FOR STARTING. HAVE YOUR INSTRUCTOR CHECK YOUR WORK. CHANGE ANYTHING THAT IS WRONG.

4. On a clean copy of the DC schematic, trace what happens for slow speed. Have your instructor check your work. Change anything that is wrong.

5. On a copy of the DC schematic, trace what happens for Fast Speed. Have your instructor check your work. Change anything that is wrong.

6. Get another student. Explain what happens on the DC schematic for Starting and Slow Speed and Fast Speed. Do the same for the conveyor motors' starting and running cycles.

7. Tell your instructor when you are ready for the examination. Complete the examination.

STUDENT HANDOUT #1

DC SYSTEM COMPONENTS

UNIT: 08 SCHEMATICS: DC CIRCUIT TRACING

AT THE END OF THIS HANDOUT THERE IS A DC PRINT. GET THE PRINT AND TAKE A FEW MINUTES TO LOOK IT OVER.

NOW, LETS LOOK AT THE PRINT AND GET TO KNOW WHAT KIND OF ELECTRICAL EQUIPMENT WE'RE DEALING WITH.

THE POWER CIRCUIT

A. THERE ARE (4) FOUR DC MOTORS ON THIS PIECE OF EQUIPMENT.

   1. MOTORS A AND B ARE THE HEAD AND TRACTION MOTOR.
   2. MOTORS C AND D ARE THE CONVEYOR MOTORS.
   3. WE KNOW THEY ARE DC MOTORS BECAUSE THEY EACH HAVE A SERIES AND SHUNT FIELD WINDING AND BECAUSE THE POWER LINES ARE MARKED L- AND L+.

B. THE TWO HEAD AND TRACTION MOTORS (A & B) ARE CONNECTED IN SERIES WITH EACH OTHER. THEY ARE ALSO IN SERIES WITH THE STARTING RESISTOR.

C. THE CONVEYOR MOTORS (C & D) ARE CONNECTED IN PARALLEL WITH EACH OTHER. THEY ARE IN SERIES WITH THE STARTING RESISTOR.

D. There are six (6) contacts in the power circuit. They are marked M1, M2, MA, C1, C2, and CA.

1. M1 and M2 contacts connect the head and traction motors to the main line. When they close the motors become energized.

2. MA contacts serve to "short out" the starting resistor after the motors have started.

3. Contacts C1 and C2 connect the conveyor motors to the main line.

4. The CA contacts close after the conveyor contacts close. They by-pass the starting resistor.

Control Circuit

A. There are two fuses which serve to protect the components and wiring of the control circuit.

B. There are three control switches: slow-fast/reset, head and traction start-stop, and conveyor start-stop.

1. Slow-fast/reset switch. This switch consists of two switches built together with one operating handle. It has three positions.

   a. Position #1, both switches are open.

   b. Position #2, the slow-fast part is closed to the slow position and the reset part is open.

c. Position #3, both switches are closed.

2. The head and traction start-stop switch is a push button switch.

3. The conveyor stop-start switch is a push button switch.

C. There are (6) six operating coils in the control circuit.

1. Coils M1, M2, and MA operate (open and close) the contacts in the power circuit of the head and traction motors.

2. Coils C1, C2, and CA operate the contacts in the power circuit of the conveyor motors.

D. There are (6) six mercury switches in the control circuit.

1. M1 mercury switch is a normally open switch.

A. The M1 mercury switch by-passes the start switch and the reset switch in the head and traction motors control circuit.

B. The M1 switch closes anytime the M1 operating coil is energized.

2. The C1 mercury switch is a normally open switch in the conveyor motor control circuit.

A. It by-passes the start switch when closed.

B. It is operated by the C1 operating coil.

3. The M2 and C2 mercury switches are time delay switches. They are normally open and close one second after their operating coils become energized.

   A. The M2 switch energizes the MA operating coil.
   B. The C2 switch energizes the CA operating coil.

4. OL1 and OL2 are normally closed mercury switches.

   A. The operating coil for OL1 is located in the power circuit of the head and traction motor.

   B. When an over current exists OL1 opens and disconnects the M1, M2, and MA operating coils.

   C. This in turn disconnects the head and traction motors.

   D. OL2 does the same job as OL1 except it protects the conveyor motor.

Field resistor

The field resistor is used to obtain two-speed operation of the head and traction motors. It is in series with the shunt field winding of both motors. The slow-fast switch will bypass the resistor when placed in the slow position. To better understand how the two speeds are accomplished, let's

REVIEW A FEW FACTS ABOUT DC MOTORS.

A. SERIES MOTORS

1. HAVE ONLY ONE FIELD WINDING.
2. THE FIELD WINDING IS CONNECTED IN SERIES WITH THE ARMATURE.
3. THE SPEED IS CONTROLLED ONLY BY THE LOAD CONNECTED TO IT.
4. IF THERE IS NOTHING HOOKED TO THE MOTOR IT WILL SPEED UP UNTIL IT FLIES APART.

B. SHUNT MOTORS

1. HAVE ONLY ONE FIELD WINDING.
2. THE FIELD WINDING IS CONNECTED IN PARALLEL WITH THE ARMATURE.
3. ITS SPEED IS CONSTANT REGARDLESS OF THE CONNECTED LEAD.

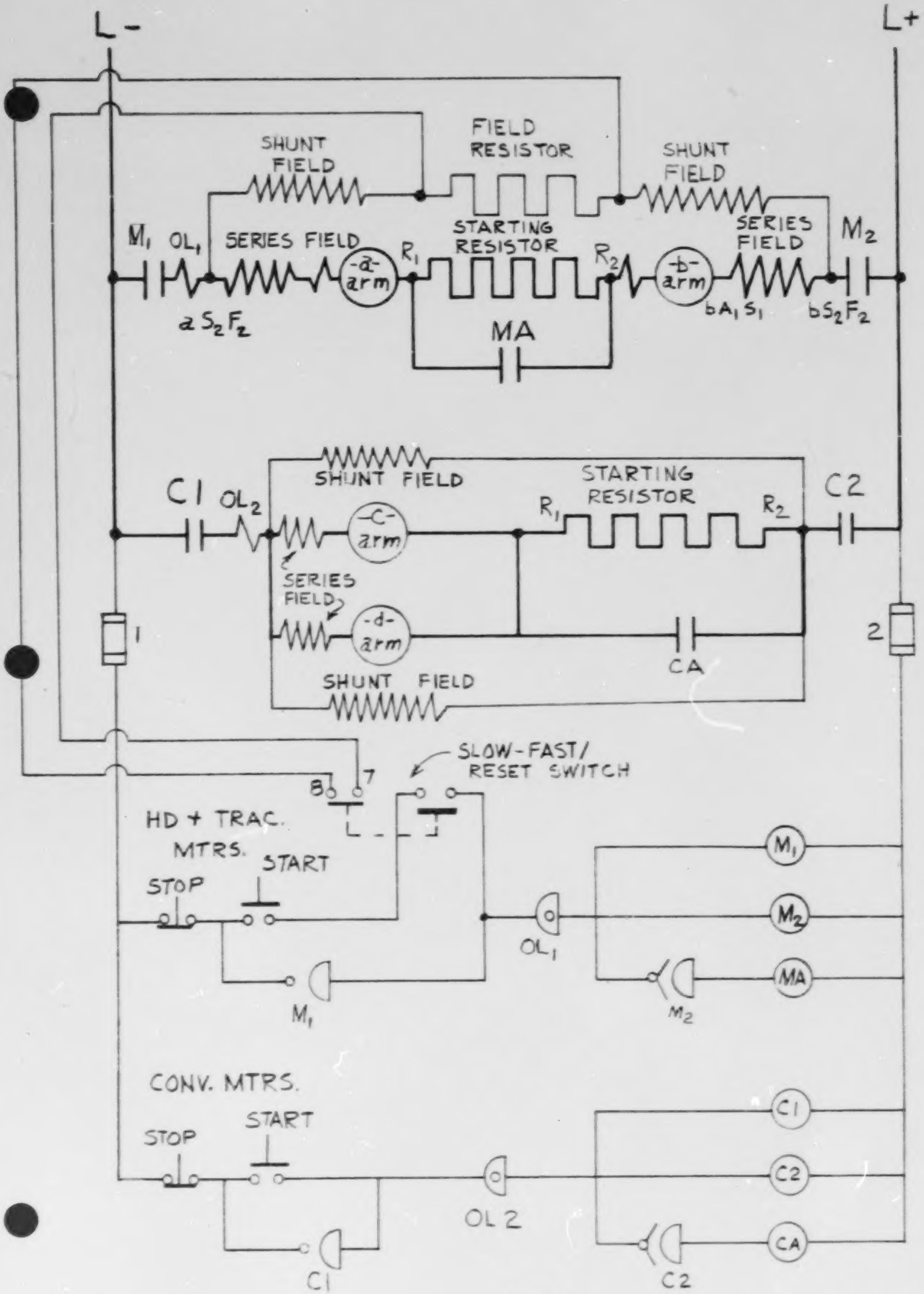
C. COMPOUND MOTORS

1. HAS TWO FIELD WINDINGS.
2. THE SERIES FIELD IS CONNECTED IN SERIES WITH THE ARMATURE FOR HIGH TORQUE.
3. THE SHUNT FIELD IS CONNECTED IN PARALLEL WITH THE

ARMATURE FOR CONSTANT SPEED.

4. IF THE SHUNT FIELD IS DISCONNECTED IT WILL ACT LIKE A SERIES MOTOR AND SPEED UP.

5. PLACING A RESISTOR IN SERIES WITH THE SHUNT FIELD WILL CAUSE IT TO BECOME WEAK. THIS PERMITS THE MOTOR TO SPEED UP. SINCE THE SHUNT FIELD IS NOT COMPLETELY DISCONNECTED, IT WILL NOT RUN FAST ENOUGH TO FLY APART.



L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
SERIES FIELD
STARTING RESISTOR
SERIES FIELD
M2
-a- arm
R1
R2
-b- arm
a S2 F2
b A1 S1
b S2 F2
MA
C1
OL2
SHUNT FIELD
STARTING RESISTOR
C2
-c- arm
R1
R2
SERIES FIELD
-d- arm
1
2
CA
SHUNT FIELD
SLOW-FAST/ RESET SWITCH
8
7
HD + TRAC. MTRS.
START
STOP
M1
M2
OL1
MA
M1
M2
CONV. MTRS.
START
STOP
C1
C2
OL 2
CA
C1
C2

STUDENT HANDOUT #2
DC SCHEMATIC TRACING

UNIT: 08 SCHEMATICS: DC CIRCUIT TRACING

NOW THAT YOU HAVE BECOME FAMILIAR WITH THE DC PRINT, LET'S TRACE THE CURRENT THROUGH THE POWER AND CONTROL CIRCUITS FOR EACH STEP OF EQUIPMENT OPERATION.

GET THE CIRCUIT PRINTS AT THE END OF THIS HANDOUT. WE WILL START WITH STEP #1.

BELOW IS THE SEQUENCE OF EVENTS WHICH HAPPENS WHEN THE HEAD AND TRACTION MOTORS ARE STARTED. FOLLOW THIS SEQUENCE ON THE STEP #1 STARTING PRINT.

CIRCUIT OPERATION STARTING CYCLE

A. THE RESET SWITCH IS CLOSED. THIS PLACES THE SLOW-FAST SWITCH IN THE SLOW POSITION.

B. THE START SWITCH FOR THE HEAD AND TRACTION MOTOR IS PRESSED (CLOSED).

   1. CURRENT NOW FLOWS FROM L-, THROUGH FUSE #1, THROUGH THE STOP SWITCH, THROUGH THE RESET SWITCH, THROUGH OL #1, THROUGH BOTH M1 AND M2 OPERATING COILS, THROUGH FUSE #2 TO L+. THE M1 AND M2 COILS ARE NOW ENERGIZED.

2. GET STEP #2, STARTING PRINT TO SEE WHAT HAPPENS WHEN M1 AND M2 OPERATING COILS ARE ENERGIZED.

   A. THE M1 COIL CLOSES THE M1 CONTACT IN THE POWER CIRCUIT. IT ALSO CLOSES THE M1 MERCURY SWITCH IN THE CONTROL CIRCUIT.

   B. THE M2 COIL CLOSES THE M2 CONTACTS IN THE POWER CIRCUIT. IT ALSO BEGINS THE M2 MERCURY SWITCH TIMING ACTION.

   C. WHEN CONTACTS M1 AND M2 CLOSE:

      1. CURRENT FLOWS THROUGH THE ARMATURES OF BOTH HEAD AND TRACTION MOTORS AND THE SERIES STARTING RESISTOR.

      2. CURRENT ALSO FLOWS THROUGH THE SHUNT FIELD WINDINGS. THIS CURRENT BY-PASSES THE FIELD RESISTOR.

3. GET STEP #3 STARTING PRINT. IN THIS PRINT, THE START SWITCH IS RELEASED (OPENED) AND THE RESET IS RELEASED (OPENED).

   A. THE CURRENT IN THE POWER CIRCUIT DOES NOT CHANGE.

   B. THE CONTROL CIRCUIT CURRENT BY-PASSES THE START SWITCH AND RESET SWITCH BY GOING THROUGH THE M1 MERCURY SWITCH.

4. Get Step #4 Starting print. The M2 delay acting mercury switch closes.

   A. This energizes the MA operating coil.

   B. When the MA operating coil is energized the MA power contacts close.

   C. The MA contacts allow motor current to by-pass the starting resistor.

   D. The starting cycle has now ended and the motors are running at slow speed.

All of the starting cycle occurs in a very short time period. The start cycle ends one second after the start and reset switch are closed.

Circuit Operation Slow Speed

A. The circuit print for slow speed operation of the head and traction motors is the same as Step #4 Starting.

B. The end of the start cycle is the slow speed operation.

Circuit Operation Fast Speed

A. Fast speed operation requires only one change. The slow-fast switch must be returned to the fast position.

B. Remember the reset switch is spring loaded. It returned to the open position at the end of the start cycle.

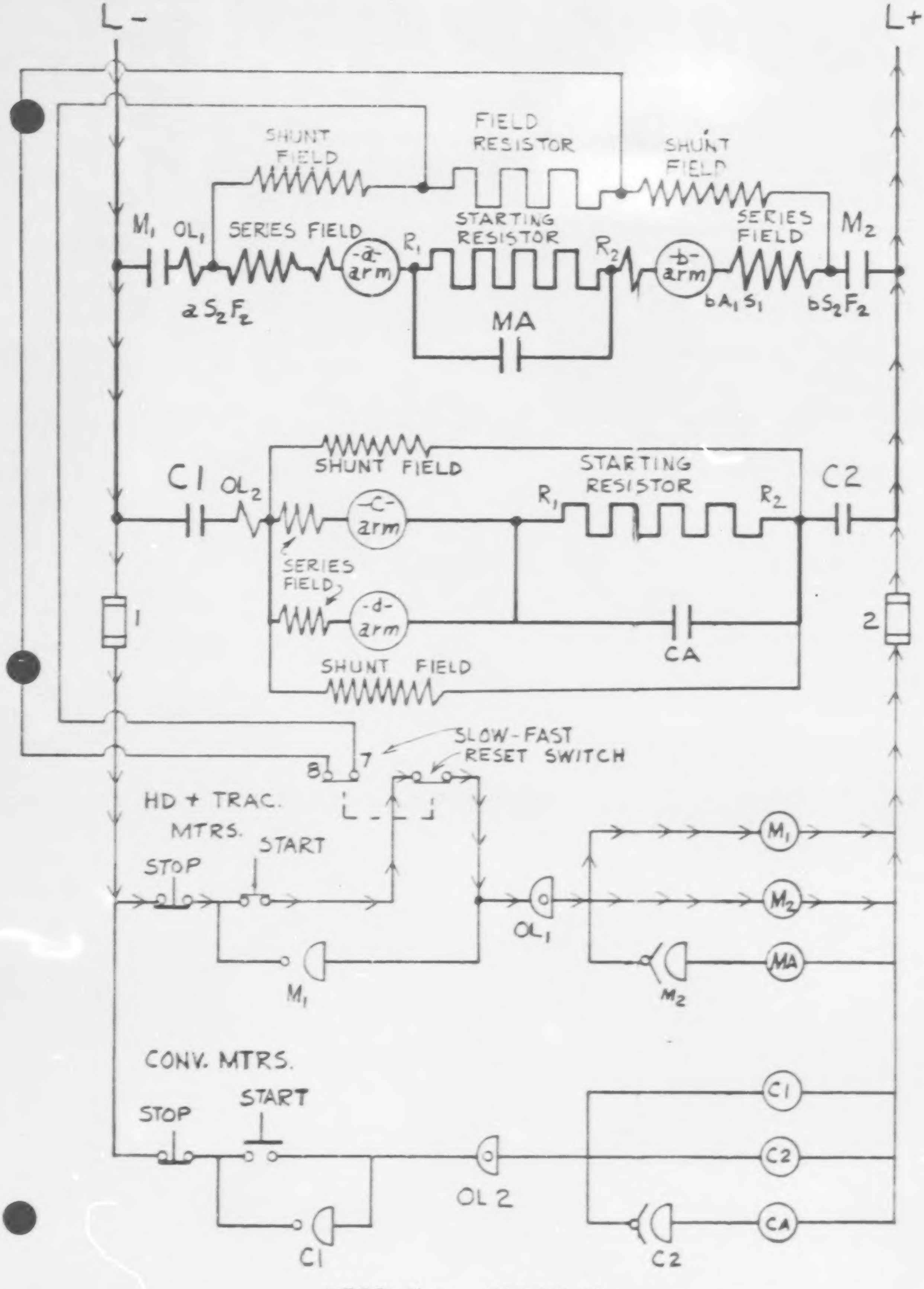
C. Placing the slow-fast/reset switch in the fast position simply opens the switch. In this position it will no longer by-pass the field resistor.

D. Look at step #5 Fast Speed Operation Print.

   1. The magnetic field produced by the shunt winding becomes weaker.

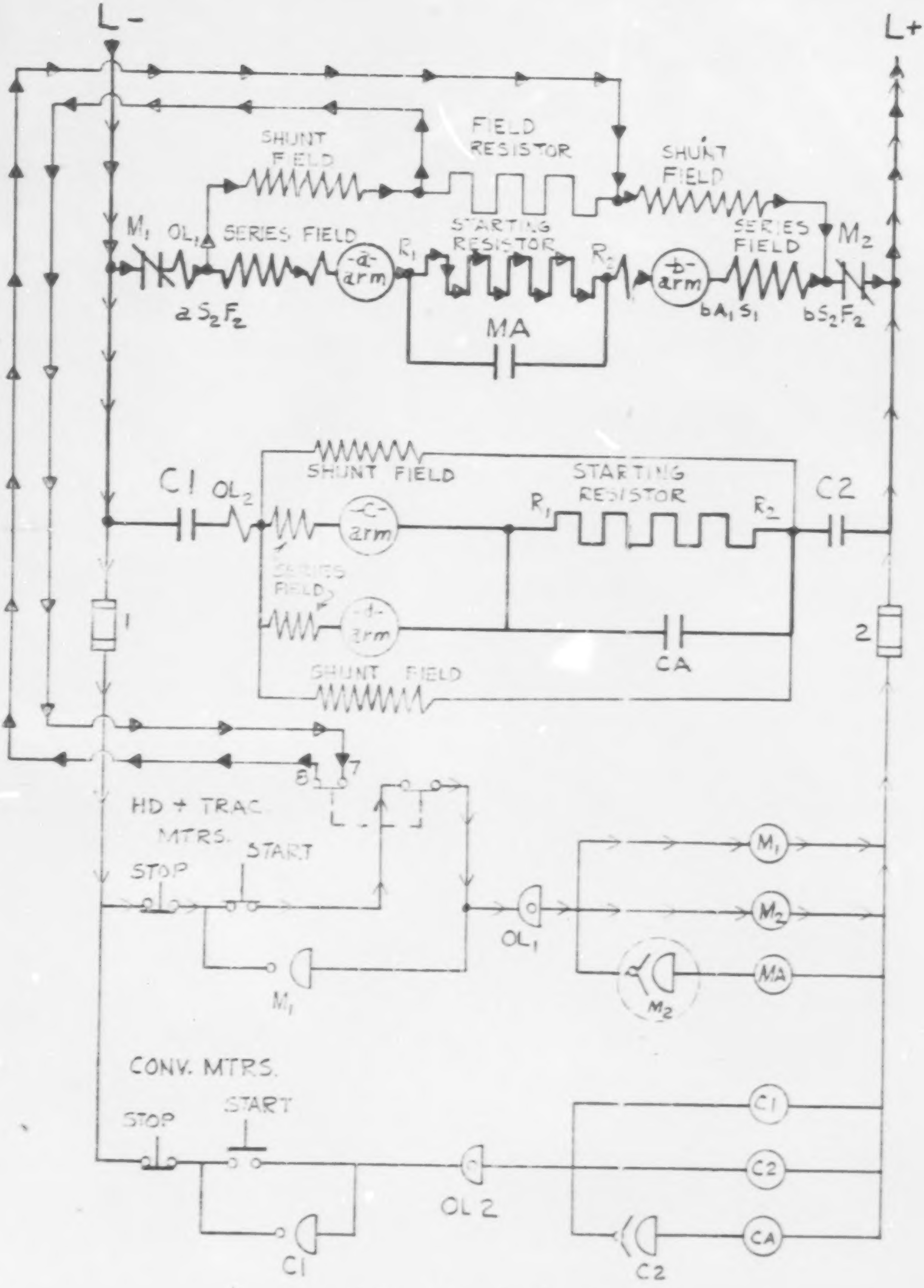
   2. This occurs becuase the field resistor lowers the amount of current passing through them.

   3. The motor begins to act more like a series motor and speeds up.


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
SERIES FIELD
-a- arm
R1
STARTING RESISTOR
R2
-b- arm
SERIES FIELD
M2
a S2 F2
bA1 S1
bS2 F2
MA
C1
OL2
SHUNT FIELD
-c- arm
STARTING RESISTOR
R1
R2
C2
SERIES FIELD
-d- arm
CA
SHUNT FIELD
1
2
8
7
SLOW-FAST RESET SWITCH
HD + TRAC. MTRS.
STOP
START
OL1
M1
M2
MA
M1
M2
CONV. MTRS.
STOP
START
OL 2
C1
C2
CA
C1
C2

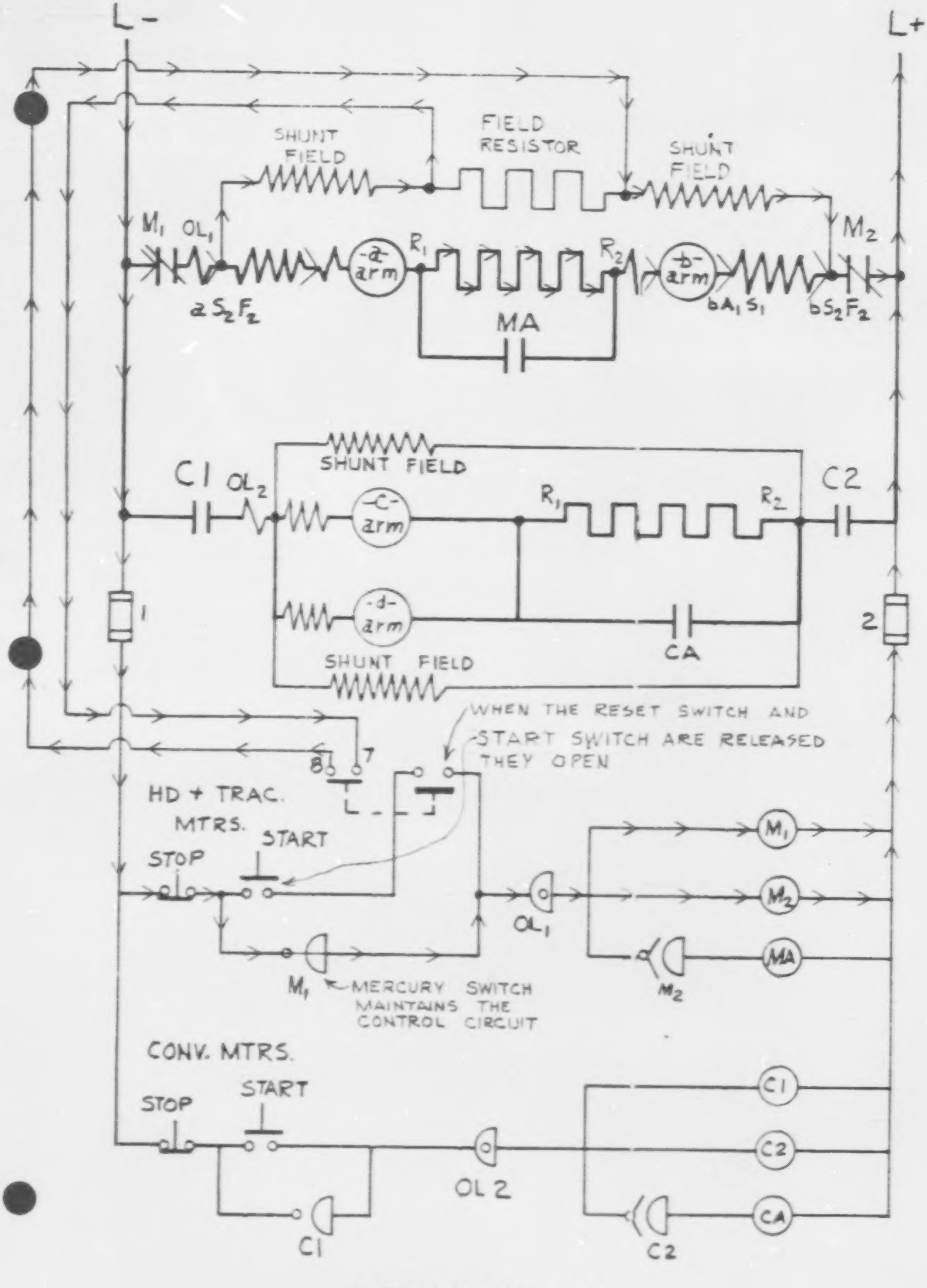
STEP #1 STARTING

8-31 278

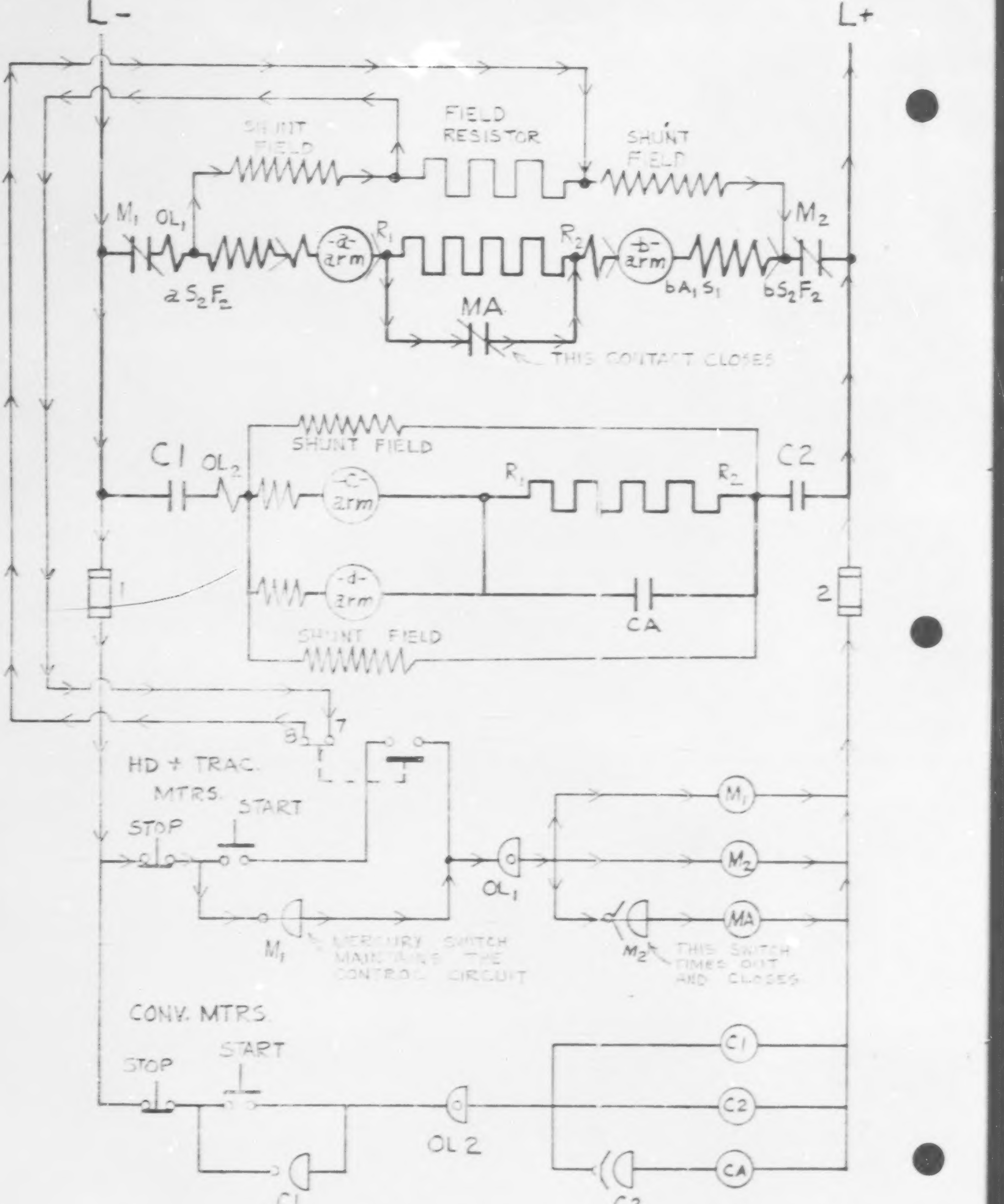

L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
SERIES FIELD
-a- arm
R1
STARTING RESISTOR
R2
-b- arm
SERIES FIELD
M2
a S2 F2
b A1 S1
b S2 F2
MA
C1
OL2
SHUNT FIELD
STARTING RESISTOR
R1
R2
C2
-c- arm
SERIES FIELD
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
STOP
START
OL1
M1
M1
M2
MA
M2
CONV. MTRS.
STOP
START
OL 2
C1
C1
C2
CA
C2

STEP #2 STARTING

8-32

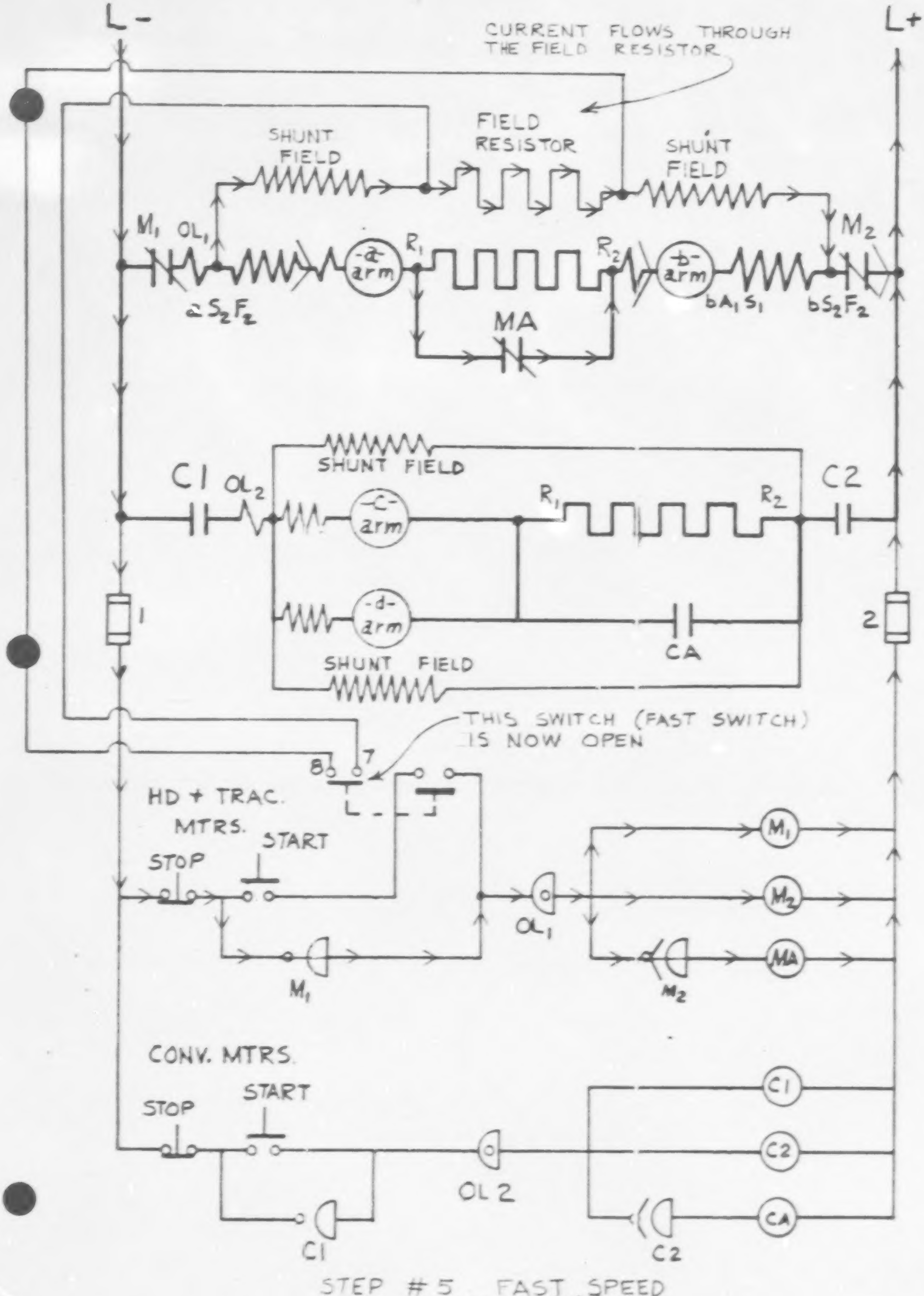

L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
M2
-a- arm
R1
R2
-b- arm
aS2F2
bA1S1
bS2F2
MA
SHUNT FIELD
C1
OL2
-c- arm
R1
R2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
WHEN THE RESET SWITCH AND START SWITCH ARE RELEASED THEY OPEN
HD + TRAC. MTRS.
START
STOP
OL1
M1
M2
MA
M1
MERCURY SWITCH MAINTAINS THE CONTROL CIRCUIT
M2
CONV. MTRS.
STOP
START
OL 2
C1
C2
CA
C1
C2

STEP # 3 STARTING
8-33

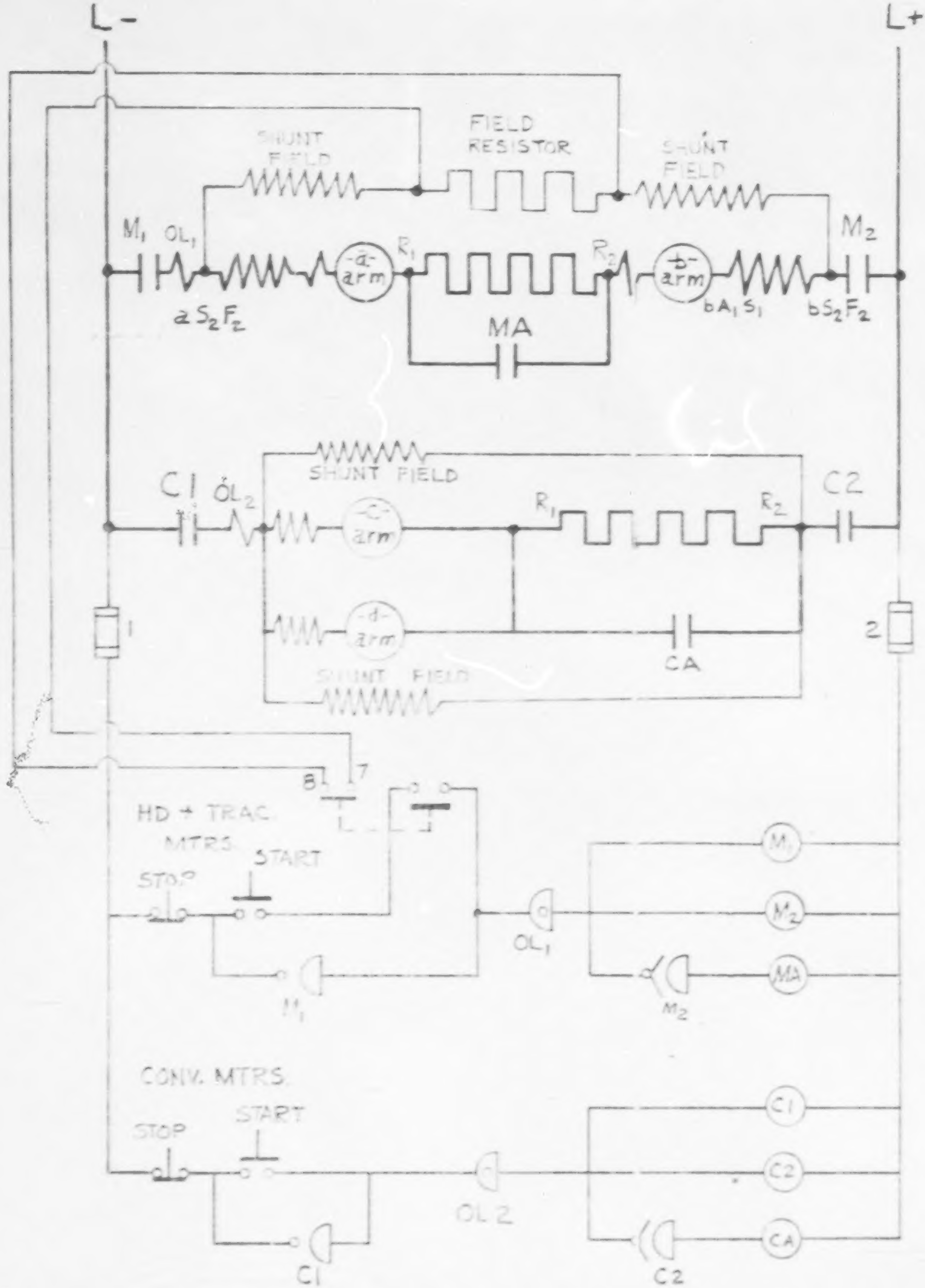

L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M_1
OL_1
-a- arm
R_1
R_2
-b- arm
M_2
aS_2F_2
bA_1S_1
bS_2F_2
MA
THIS CONTACT CLOSES
SHUNT FIELD
C1
OL_2
-c- arm
R_1
R_2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
STOP
START
OL_1
M_1
M_2
MA
M_1
MERCURY SWITCH MAINTAINS THE CONTROL CIRCUIT
M_2
THIS SWITCH TIMES OUT AND CLOSES
CONV. MTRS.
STOP
START
OL 2
C1
C2
CA
C1
C2

STEP # 4 STARTING + SLOW SPEED

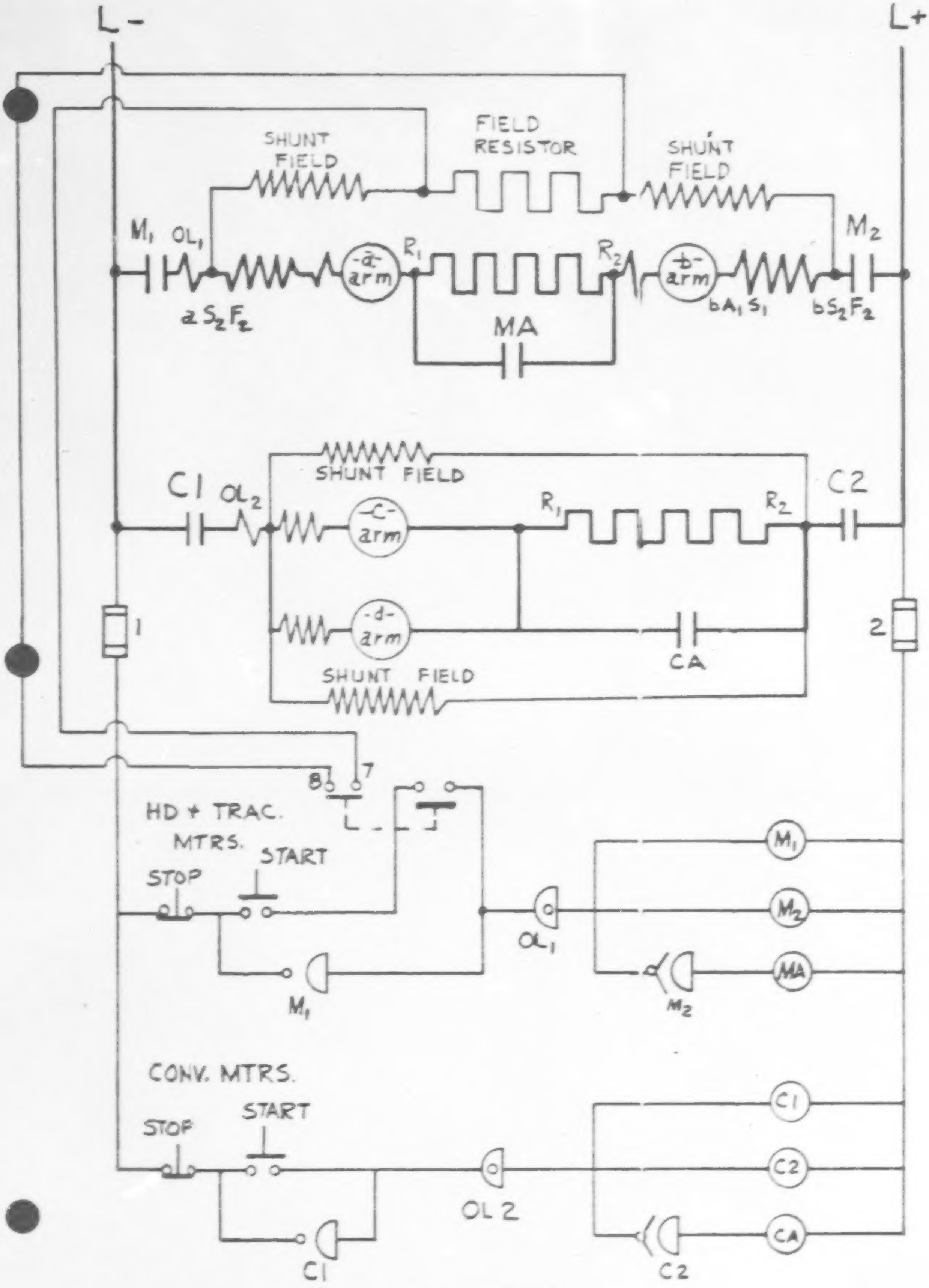
8-34


L-
L+
CURRENT FLOWS THROUGH THE FIELD RESISTOR
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M_1
OL_1
aS_2F_2
-a- arm
R_1
R_2
-b- arm
bA_1S_1
M_2
bS_2F_2
MA
SHUNT FIELD
C1
OL_2
-c- arm
R_1
R_2
C2
1
2
-d- arm
CA
SHUNT FIELD
THIS SWITCH (FAST SWITCH) IS NOW OPEN
8
7
HD + TRAC. MTRS.
STOP
START
M_1
OL_1
M_1
M_2
MA
M_2
CONV. MTRS.
STOP
START
C1
OL 2
C1
C2
CA
C2

STEP # 5 FAST SPEED

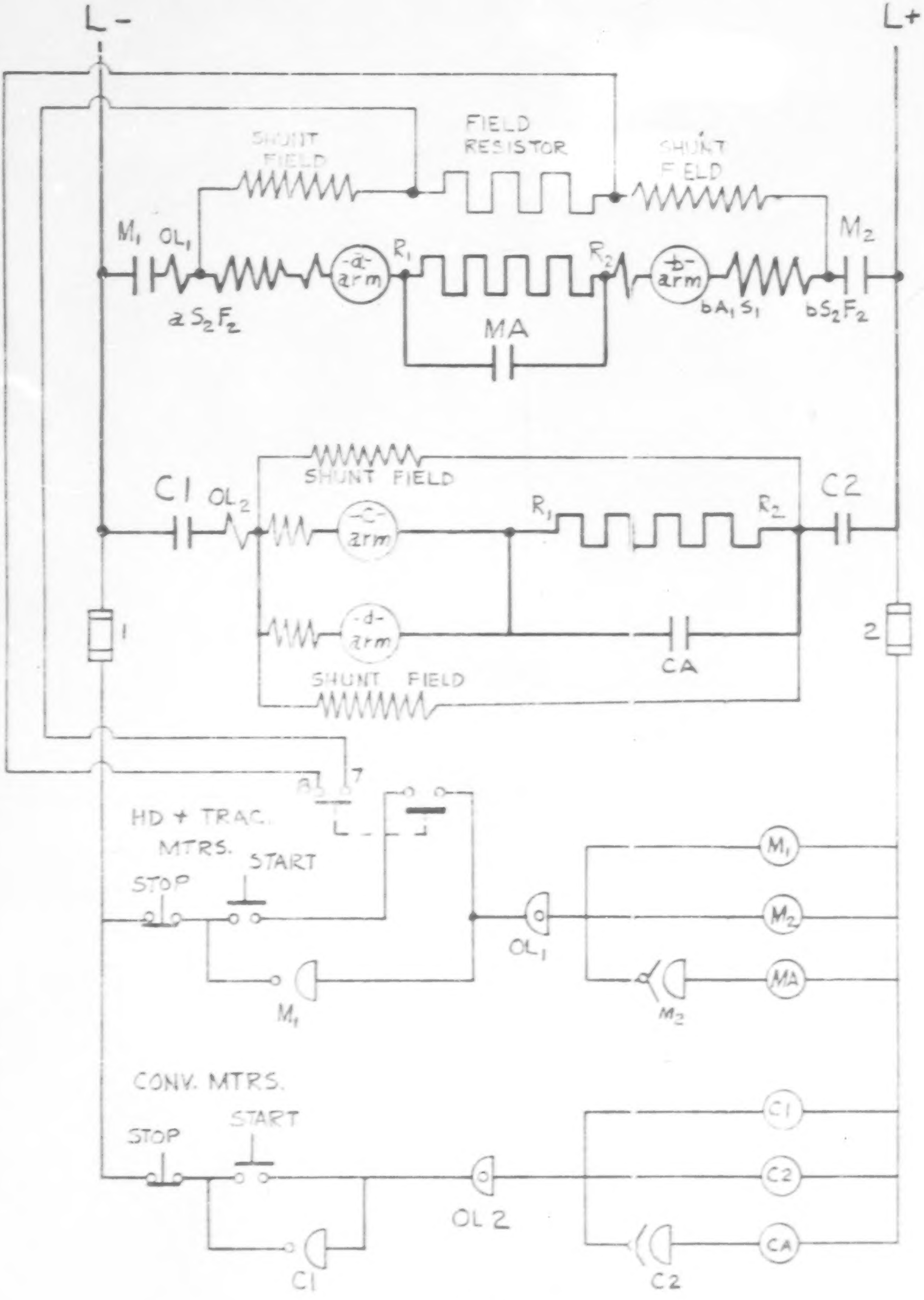

L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
M2
-a- arm
R1
R2
-b- arm
a S2 F2
b A1 S1
b S2 F2
MA
SHUNT FIELD
C1
OL2
-c- arm
R1
R2
C2
1
2
-d- arm
CA
SHUNT FIELD
8
7
HD + TRAC. MTRS.
START
STOP
M1
M2
MA
OL1
M1
M2
CONV. MTRS.
STOP
START
C1
C2
CA
OL 2
C1
C2

SLOW SPEED
8-36


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
-a- arm
R1
R2
-b- arm
M2
a S2 F2
b A1 S1
b S2 F2
MA
SHUNT FIELD
C1
OL2
-c- arm
R1
R2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
STOP
START
M1
M2
MA
OL1
M1
M2
CONV. MTRS.
STOP
START
C1
C2
CA
OL 2
C1
C2

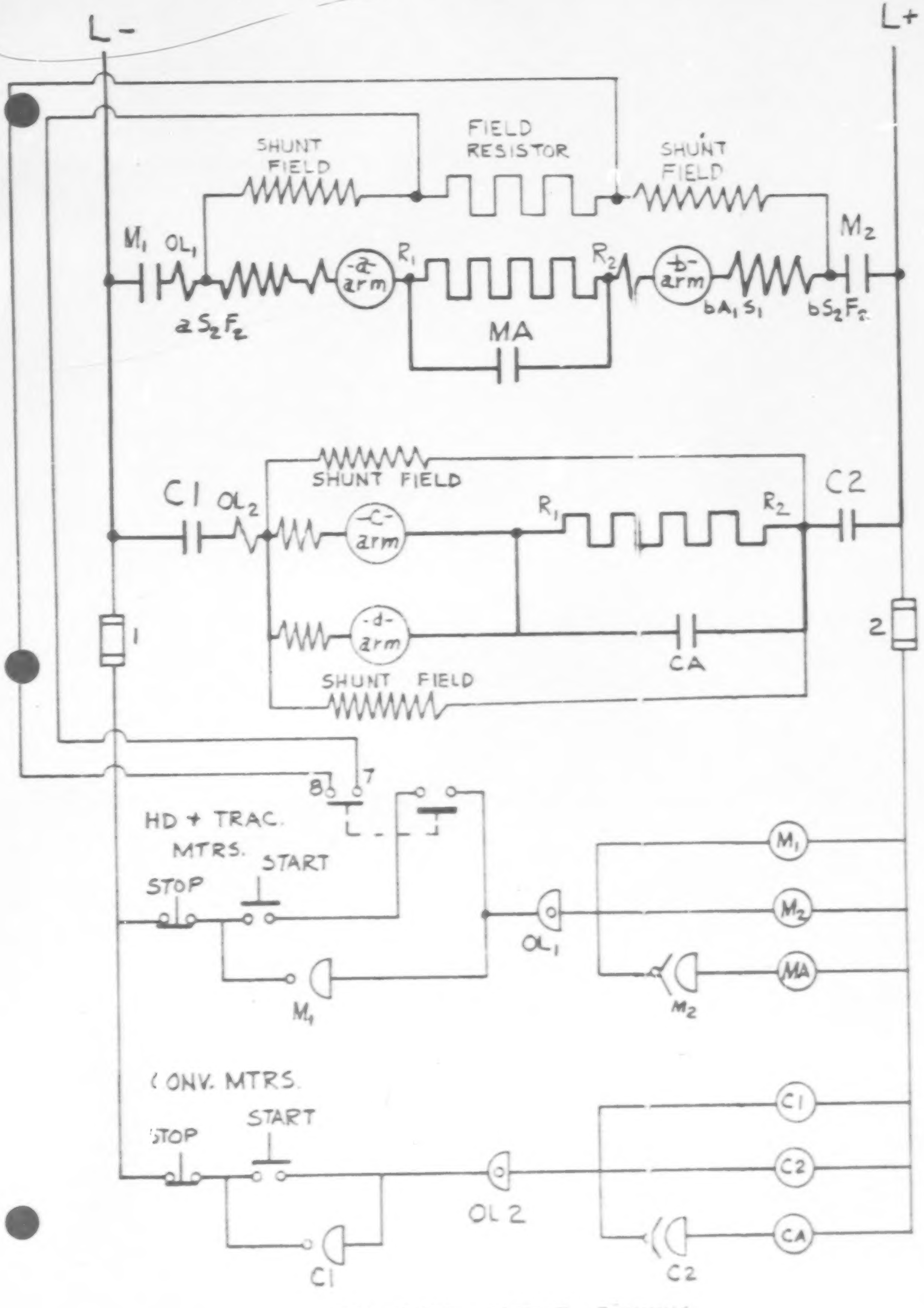
FAST SPEED

8-37


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
-a- arm
R1
R2
-b- arm
M2
a S2 F2
b A1 S1
b S2 F2
MA
SHUNT FIELD
C1
OL2
-c- arm
R1
R2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
STOP
START
M1
OL1
M1
M2
MA
M2
CONV. MTRS.
STOP
START
C1
OL 2
C1
C2
CA
C2

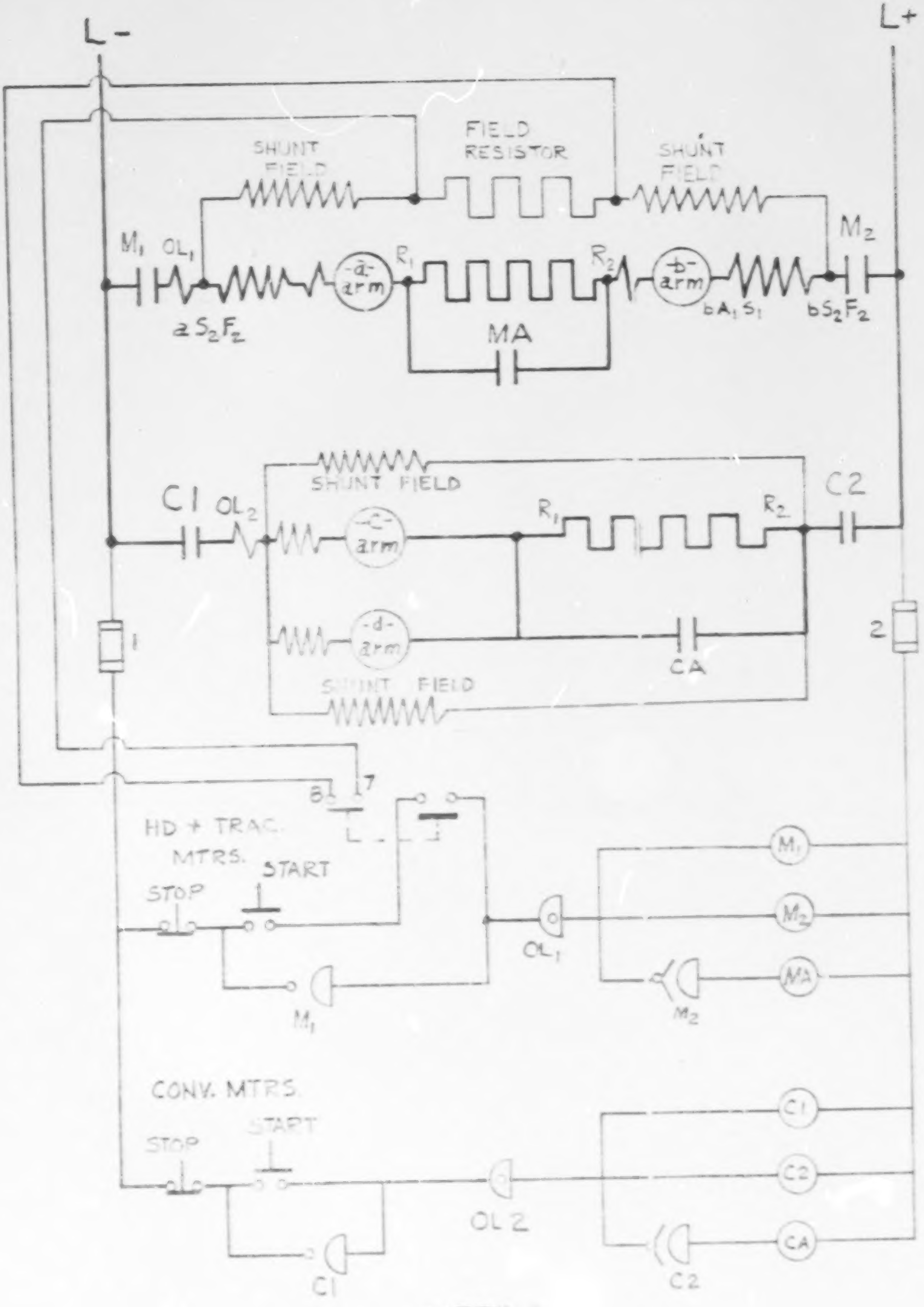
CONVEYOR MOTOR STARTING

8-38


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
-a- arm
R1
R2
-b- arm
M2
aS2F2
bA1S1
bS2F2
MA
SHUNT FIELD
C1
OL2
-c- arm
R1
R2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
STOP
START
M1
OL1
M1
M2
MA
M2
CONV. MTRS.
STOP
START
C1
OL 2
C2
C1
C2
CA

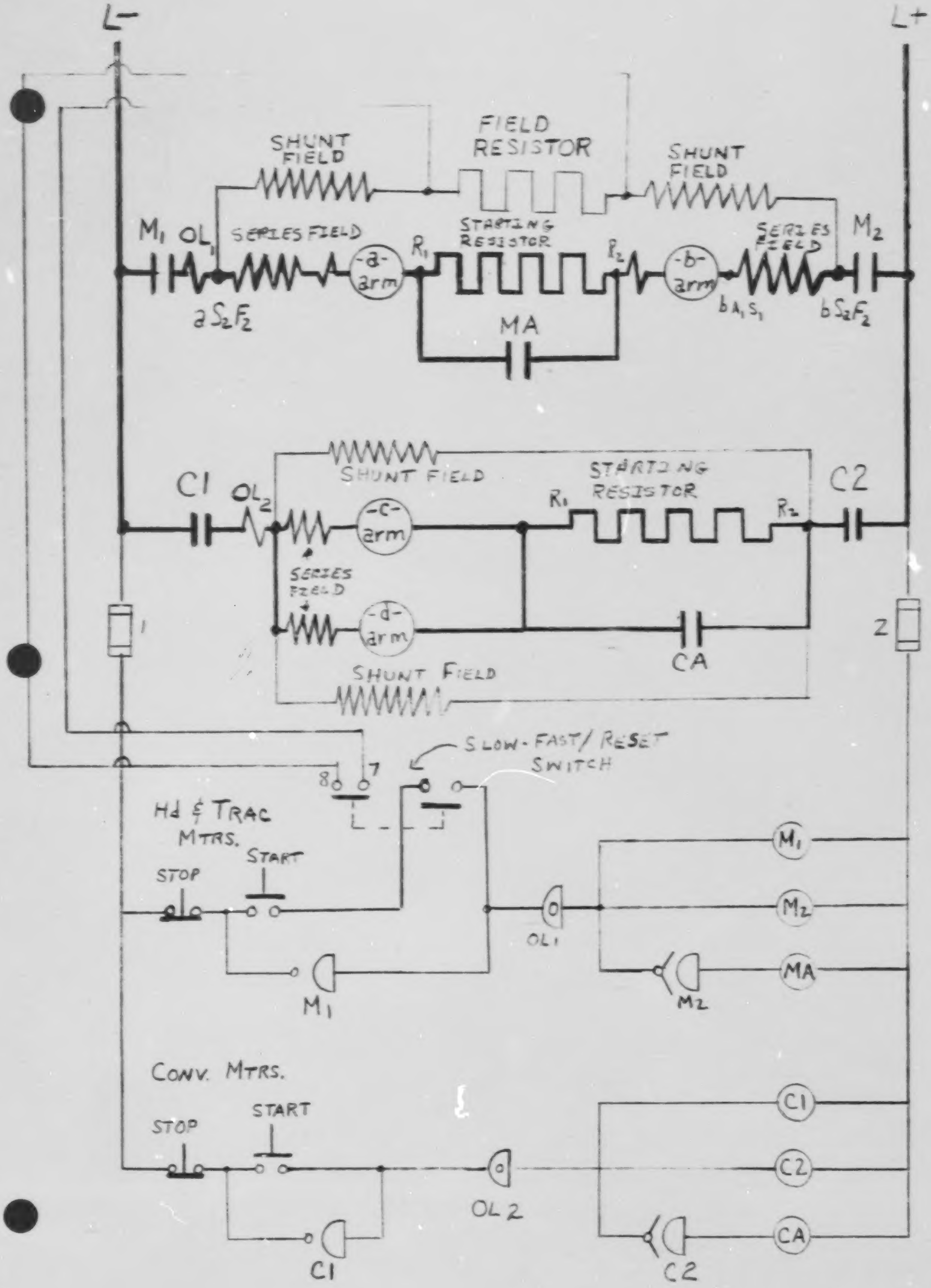
CONVEYOR MOTOR RUNNING
8-39

250


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
-a- arm
R1
R2
-b- arm
M2
aS2F2
bA1S1
bS2F2
MA
C1
OL2
SHUNT FIELD
-c- arm
R1
R2
C2
-d- arm
CA
SHUNT FIELD
1
2
8
7
HD + TRAC. MTRS.
START
STOP
OL1
M1
M1
M2
MA
M2
CONV. MTRS.
START
STOP
OL 2
C1
C2
CA
C1
C2

STARTING

8-40


L-
L+
SHUNT FIELD
FIELD RESISTOR
SHUNT FIELD
M1
OL1
SERIES FIELD
-a- arm
R1
STARTING RESISTOR
R2
-b- arm
SERIES FIELD
M2
a S2 F2
b A1 S1
b S2 F2
MA
SHUNT FIELD
C1
OL2
STARTING RESISTOR
R1
R2
C2
-c- arm
SERIES FIELD
-d- arm
CA
1
2
SHUNT FIELD
SLOW-FAST/ RESET SWITCH
8
7
Hd & TRAC MTRS.
STOP
START
M1
M2
MA
OL1
M1
M2
CONV. MTRS.
STOP
START
C1
C2
CA
OL 2
C1
C2

STUDENT COMPETENCY SHEET #1

UNIT: 09 SCHEMATICS: AC SYMBOLS

COMPETENCY STATEMENT: IDENTIFIES AC COMPONENT SYMBOLS AND EXPLAINS USE OF COMPONENTS

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT AC COMPONENT SYMBOLS AND ON HOW THESE COMPONENTS ARE USED.

CONDITIONS: YOU HAVE 20 MINUTES TO DO THIS. YOU MAY NOT USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "AC SYMBOLS," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS ON STUDY SHEET #1.
2. GET SOME SMALL CARDS FROM THE INSTRUCTOR. DRAW THE SYMBOLS FOR THE FOLLOWING COMPONENTS ON THE CARDS. PUT JUST ONE SYMBOL ON EACH CARD. PUT THE NAME FOR THE SYMBOL ON THE BACK OF THE CARD.

   AC LINE STARTER
   OVERLOAD RELAY CONTACTS
   OVERLOAD RELAY HEATER
   INTERLOCK
   SWITCH IN RESET POSITION
   FUSE
   CIRCUIT BREAKER
   METHANE MONITOR

3. GET ANOTHER STUDENT. GIVE THE STUDENT YOUR SMALL CARDS WITH SYMBOLS ON THEM. WHEN THE STUDENT SHOWS YOU A CARD, NAME THE SYMBOL.

4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
AC SYMBOLS

UNIT: 09 SCHEMATICS: AC SYMBOLS

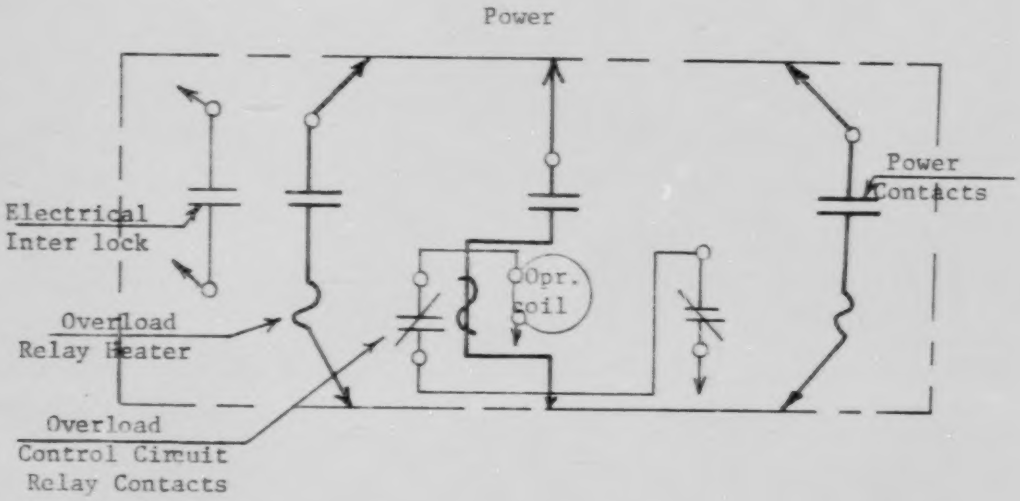
PURPOSE

TO CONTINUE OUR REVIEW OF SYMBOLS, WE'RE GOING TO LOOK AT THE ONES FOR AC COMPONENTS. DURING YOUR STUDY, LOOK AT THE AC COMPONENTS ON THE DISPLAY TABLE. ALSO USE THE COPY OF THE AC SCHEMATIC AT THE END OF THIS HANDOUT.

SOME COMPONENTS AND SYMBOLS USED ON AC SCHEMATICS ARE THE SAME AS THOSE ON DC SCHEMATICS. PUSH BUTTONS AND MERCURY TUBES ARE TWO EXAMPLES. WE WILL NOT STUDY THESE AGAIN. HOWEVER, SWITCH POSITIONS AND COIL MARKINGS WILL BE STUDIED.

AC LINE STARTER

THE AC LINE STARTER IS LIKE THE DC CONTACTORS. THE SYMBOL FOR THE AC LINE STARTER IS BELOW.


Power
Power Contacts
Electrical Inter lock
Opr. coil
Overload Relay Heater
Overload Control Circuit Relay Contacts

AC Line Starter Symbols

The broken line around the symbol tells us that these parts are in a single unit.

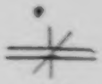
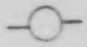
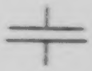
You should be able to see some symbols like those on the DC schematic you have studied. These are:

1. Power circuit (heavy dark lines)
2. Operating coil
3. Contacts in power circuit

There are some new ones too. These are:

1. Overload control circuit, relay contacts
2. Overload relay heaters
3. Electrical interlock

Some of the symbols within the line starter may also appear other places on AC schematics. These are:

1. Overload control circuit relay contacts 
2. Operating coils 
3. Power contacts 

Comparisons of AC Line Starter to DC Contactors

1. Power Contactors:

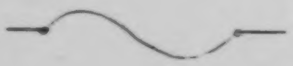
DC contactors have one set of power contactors. This set has an upper contact and a lower contact. This is because DC supply current is going in and returning on two conductors. The AC line starter also has power coming in and returning. AC power in this case is three phase. This means that there are three power leads and a set of contacts for each lead. For this reason the AC line starter has three complete sets of contacts. As the operating coil energizes, all three sets of contacts will close at the same time. This connects the AC motor to the power source.

2. Overload Relay Contacts:

The symbol shows they are normally closed contacts. They are in the operating circuit. They may be magnetically operated mercury tubes. They may also be thermally operated. Thermally means they operate as a result of heat caused by extra current.

3. Electrical Interlock: N.C. —||—

In DC circuits we called this a holding circuit. It does the same thing in the AC circuit with one difference. As the power contacts close one of the movable power contacts will mechanically activate the interlock contact. The interlock contact will then maintain the circuit to the operating coil, and the start button can be released.

4. Overload Relay Heater: 

This symbol is for an overload relay heater. It is sometimes called a heater, or heater strip. Heaters are connected in the power circuit. Heat is produced in the power circuit due to the amount of current flowing. Next to these heaters is a metal disc that changes when overheated. If too much current flows, the heater will heat up the disc. This causes the disc to change and mechanically opens a set of contacts in the operating circuit. This de-energizes the operating coil and stops current flow in the power circuit.

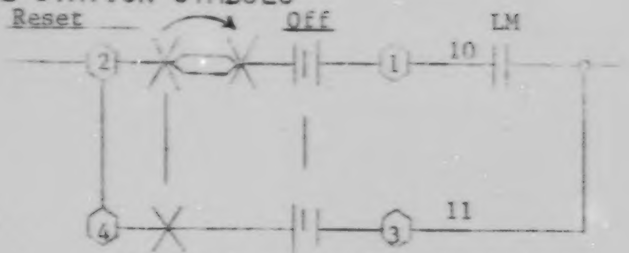
5. Operating Coils —○—

Operating coil symbols on AC schematics look the same as on DC schematics, but they tell us new information. Look at the AC schematic. Look near the bottom left side, at the "main mtrs" section. Find the coils marked RM, LM, and TR1. Now look at power contactors for the main motors. They are at the top right. You will see this:

a. RM is the Right Main Motor.
b. LM is the Left Main Motor.
c. TR1 is the Timing Relay Coil #1. This operates TR1 N.O. time delay closing, mercury switch.

Study this section of the AC schematic for a moment. Notice how TR2 mercury tube connects to the RM coil. Which of the main motors do you think would start first? Of course, the left motor would because RM is Time Delayed, isn't it?

6. CONTROL STATION SYMBOLS


Reset
Off
LM
2
10
1
4
3
11

Main Motor Switch Positions

LOOK AT THE FIGURE ABOVE. THESE SYMBOLS MEAN:

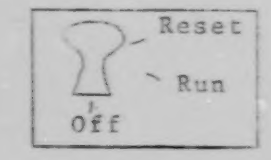
A. X CLOSED WHEN SWITCH ROTATES TO LEFT

B. ⬡ NUMBER OF THE CONNECTING TERMINALS

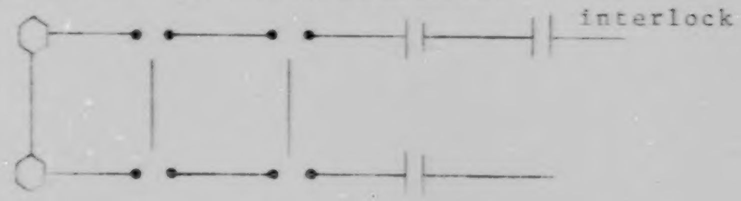
C. ⤻ SPRING RETURNED IN DIRECTION OF ARROW

D. X⊂⊃X BOTH CLOSED AND INTERCONNECTED

SWITCH OPERATION. THESE PICTURES SHOW HOW THE SWITCH OPERATES AND HOW IT IS SWOWN ON AN AC SCHEMATIC.

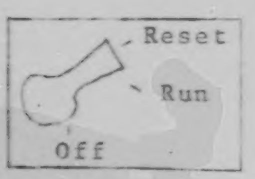

Reset
Run
Off

Switch Off

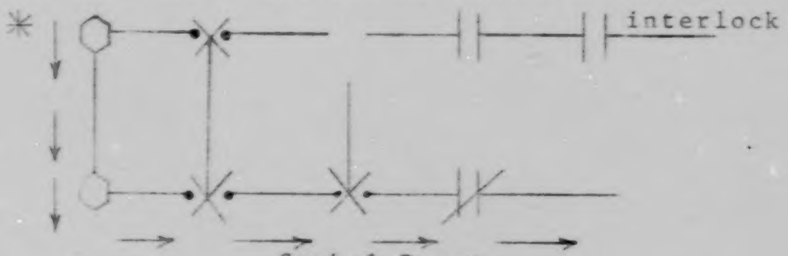


Symbol Off

WITH THE SWITCH IN THE "OFF" POSITION NO CONTACT IS MADE.

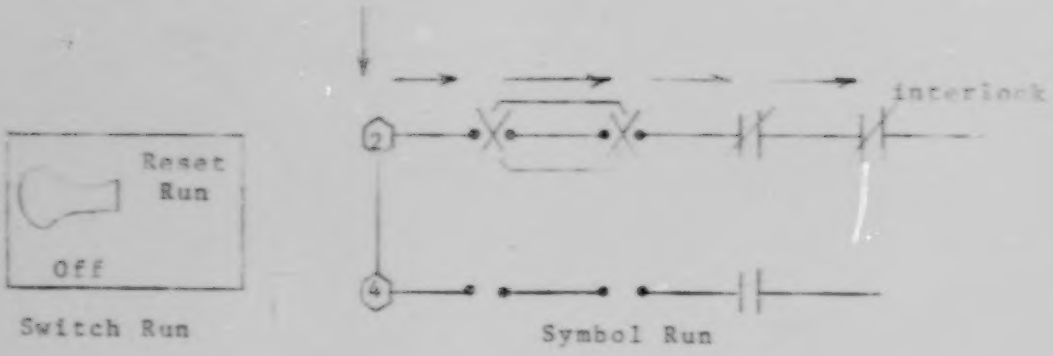

Reset
Run
Off

Switch Reset



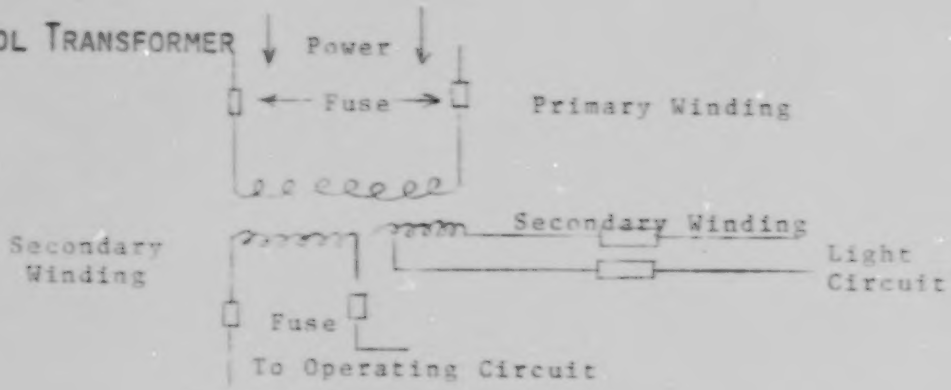
Symbol Reset

MOTOR STARTS WHEN SWITCH IS IN "RESET" POSITION.


Reset
Run
Off
Switch Run
interlock
2
4
Symbol Run

SWITCH IS SPRING RETURNED TO RUN POSITION WHEN OPERATOR RELEASES IT.

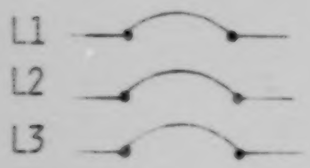
7. CONTROL TRANSFORMER


Power
Fuse
Primary Winding
Secondary Winding
Secondary Winding
Light Circuit
Fuse
To Operating Circuit

CONTROL TRANSFORMER

THE FIGURE ABOVE IS WHAT IS SHOWN ON MOST AC SCHEMATICS FOR CONTROL TRANSFORMERS. THE MAIN POWER TRANSFORMERS ARE NOT SHOWN. YOU WILL SEE THIS SYMBOL AGAIN ON SOLID-STATE AC DIAGRAMS.

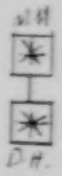
8. CIRCUIT BREAKERS



SYMBOL, CIRCUIT BREAKER

This symbol shows the main circuit breaker. The main circuit breaker connects and disconnects the machine to the main power source.

9. Methane Monitor and Detector Head



These two devices are being studied for the first time. By law they are on many machines. Notice the R_2 coil at the top center of your AC schematic. When the methane monitor senses unsafe quantities of gas through the detector head, it will not permit the machine to start. If the machine is running and gas is present in unsafe quantity, the machine will cut off. The methane monitor and detector head are located just below center of your AC schematic and are in the operating circuit. These components must NEVER be bypassed in the circuit.

10. Ammeters

There is one ammeter for the main motors and one for the conveyor motor. They are operated by current transformers. There is one lead to each of the motors mentioned. The current transformers are marked CT1, CT2, and CT3. They are located on the top leads to each of the three motors.

STUDY SHEET #1

UNIT: 09 SCHEMATICS: AC SYMBOLS

ANSWER THESE QUESTIONS.

1. DRAW THE SYMBOL FOR AN AC LINE STARTER. LABEL ALL PARTS.

2. HOW MANY SETS OF CONTACTS CLOSE TO CONNECT AN AC MOTOR TO A THREE-PHASE POWER SOURCE? CIRCLE THE CORRECT ANSWER.

   1 2 3 4

3. WHAT MAKES OVERLOAD RELAY CONTACTS OPEN? CIRCLE THE CORRECT LETTER.

   A. AN OPERATING COIL

   B. A POWER CONTACT

   C. HEAT CAUSED BY HIGH SPEED

   D. HEAT CAUSED BY EXTRA CURRENT

4. IS AN OVERLOAD RELAY HEATER CONNECTED IN THE OPERATING CIRCUIT? CIRCLE THE CORRECT ANSWER.

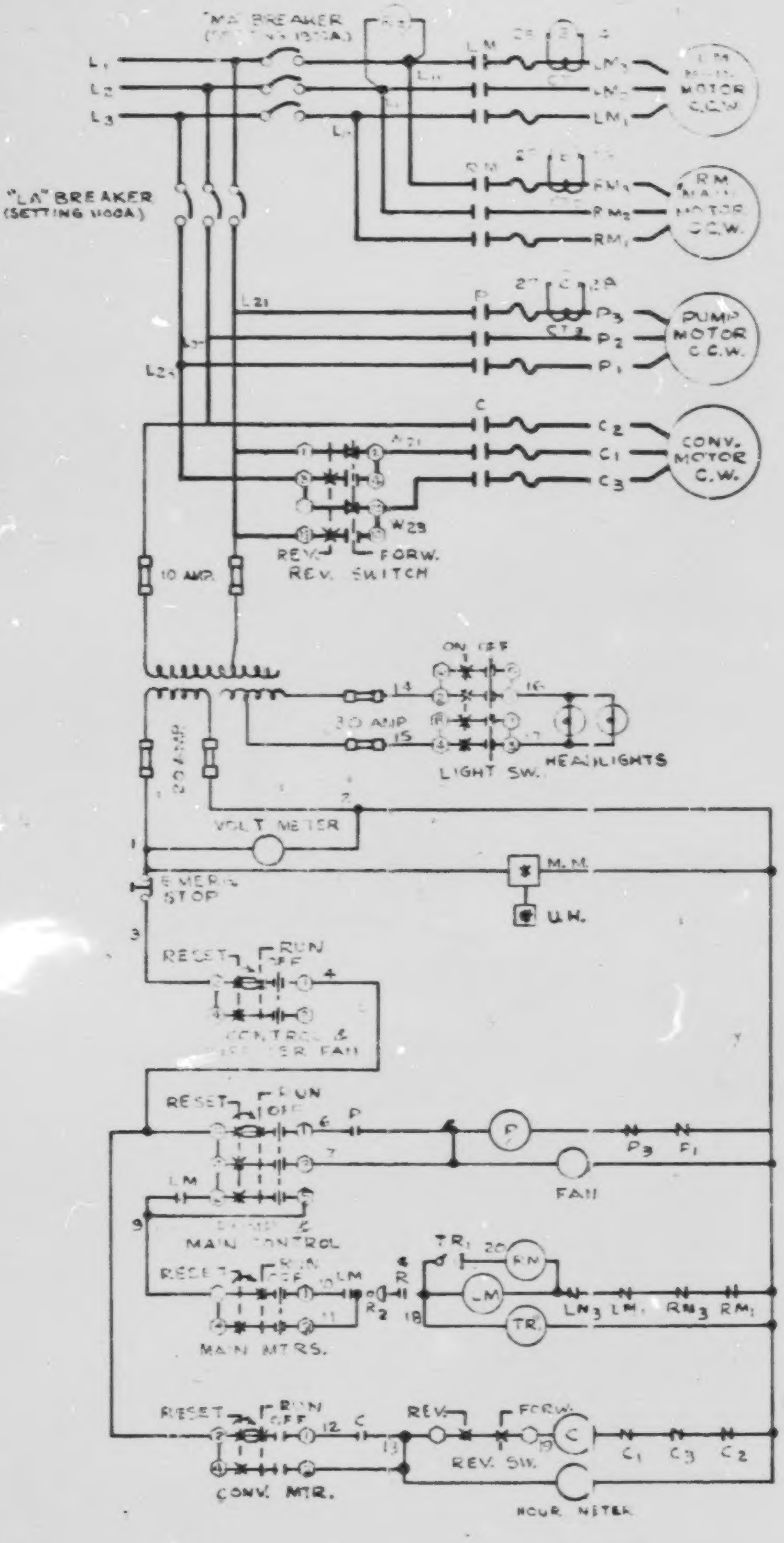
   YES NO

5. DRAW SYMBOLS FOR A SWITCH IN THE "RESET" POSITION. LABEL ALL PARTS AND SHOW HOW CURRENT FLOWS.

6. DRAW THE SYMBOL FOR A CONTROL TRANSFORMER. LABEL ALL PARTS.

7. DRAW THE SYMBOLS NEEDED TO SHOW A MAIN CIRCUIT BREAKER FOR A THREE-PHASE POWER SOURCE. LABEL ALL PARTS.

8. EXPLAIN HOW A METHANE MONITOR WORKS IF THE MACHINE IS RUNNING.


"MA" BREAKER
"LA" BREAKER
(SETTING 1100A)
L1
L2
L3
LM
LM3
LM2
LM1
LM MAIN MOTOR C.C.W.
RM
RM3
RM2
RM1
RM MAIN MOTOR C.C.W.
P
P3
P2
P1
PUMP MOTOR C.C.W.
CT2
L21
L24
C
C2
C1
C3
CONV. MOTOR C.W.
W29
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
30 AMP
15
17
LIGHT SW.
HEADLIGHTS
20 AMP
2
VOLT METER
1
M.M.
EMERG. STOP
U.H.
3
RESET
RUN
OFF
4
CONTROL & FAN
6
7
P
F
P3
F1
FAN
9
LM
PUMP & MAIN CONTROL
TR1
20
RM
R
10
LM
R2
18
TR
LN3
LM1
RM3
RM1
11
MAIN MTRS.
12
C
13
REV.
FORW.
19
REV. SW.
C1
C3
C2
CONV. MTR.
HOUR METER

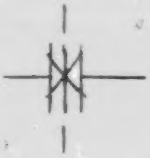
STUDENT EXAMINATION #1

UNIT: 09 SCHEMATICS: AC SYMBOLS

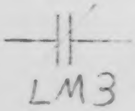
1. DRAW THE FOLLOWING SYMBOLS:
   - A. ELECTRICAL INTERLOCK
   - B. POWER CONTACTORS FOR A THREE-PHASE MOTOR
   - C. CIRCUIT BREAKER
   - D. HEATER
   - E. A SINGLE CONTACT REPRESENTING AN OVERLOAD DEVICE

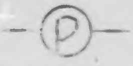
2. HOW MANY LEADS ARE THERE TO A THREE-PHASE MOTOR?

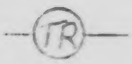
3. HOW MANY SETS OF CONTACTS WOULD EACH LINE STARTER HAVE IN AN AC SCHEMATIC THAT SHOWS THREE-PHASE POWER?

4. WHAT DOES THE FOLLOWING SYMBOL MEAN? 

5. GIVE THE SPECIFIC PURPOSE OF EACH OF THE FOLLOWING SYMOLS:

A. 

B. 

C. 

STUDENT COMPETENCY SHEET #1

UNIT: 09 SCHEMATICS: AC CIRCUIT TRACING

COMPETENCY STATEMENT: TRACES CURRENT FLOW ON AN AC SCHEMATIC AND EXPLAINS OPERATION.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. TRACE WITH A PENCIL THE CURRENT FLOW ON AN AC SCHEMATIC.
2. EXPLAIN THE OPERATION OF THE CIRCUITS YOU TRACE TO THE INSTRUCTOR.

CONDITIONS: YOU HAVE AN AC SCHEMATIC. YOU MAY NOT USE REFERENCES. YOU HAVE 20 MINUTES TO DO THIS.

STANDARD: ALL YOUR TRACING AND EXPLAINING MUST BE CORRECT. THIS MEANS THAT THE CIRCUITS REALLY WOULD WORK LIKE YOU SAY.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "SCHEMATICS: AC" FROM THE INSTRUCTOR. READ IT.

2. GET A CLEAN COPY OF THE AC SCHEMATIC. TRACE WHAT HAPPENS FOR EACH OF THESE:

   A. STARTING PUMP MOTOR
   B. HOLDING CIRCUIT FOR PUMP MOTOR

c. Starting Left Main Motor

d. Starting Right Main Motor

After you trace each step, have the instructor check your work. Change anything that is wrong.

3. Get another student. Explain what happens on the AC schematic for each of these:

   a. Starting Pump Motor
   b. Holding Circuit for Pump Motor
   c. Starting Left Main Motor
   d. Starting Right Main Motor

4. Tell the instructor when you are ready for the examination. Complete the examination.

SCHEMATICS: AC
STUDENT HANDOUT #1

UNIT: 09 SCHEMATICS: AC CIRCUIT TRACING

TO START PUMP MOTOR THE FOLLOWING SEQUENCE IS USED. LOOK AT STEP 1 OF THE AC SCHEMATIC AS YOU READ THIS.

1. MA BREAKERS ARE CLOSED.
2. LA BREAKERS ARE CLOSED.
3. R_2 RELAY (TOP OF DIAGRAM) IS ENERGIZED FROM L-11 AND L-12 IN THE POWER CIRCUIT. VOLTMETER, METHANE MONITOR (M.M.), AND DETECTOR HEAD (D.H.) GET POWER.
4. CONTROL AND DIFFUSER FAN SWITCH IS IN "RUN" POSITION.
5. PUMP AND MAIN CONTROL SWITCH IS IN "RESET" POSITION.
6. WITH THE PUMP AND MAIN CONTROL SWITCH IN THE "RESET" POSITION, THE PUMP AND MAIN CONTROL CIRCUIT IS COMPLETED THROUGH (FAN) COIL AND (P) COIL.
7. THE "P" LINE STARTER CLOSES AND THE PUMP MOTOR STARTS.

YOU SHOULD REMEMBER THE FOLLOWING POINTS ABOUT STARTING THE PUMP MOTOR.

1. THE CONTROL AND DIFFUSER FAN CIRCUIT MUST BE CLOSED. THIS HAPPENS WHEN THE CONTROL AND DIFFUSER FAN SWITCH IS IN THE "RUN" POSITION.

2. Both the Emergency Stop Switch and the Control and Diffuser Fan Switch are in series with the operating circuit. No power will flow in the operating circuit unless both switches are closed.

To have a holding circuit and to have the Pump Motor run, the following sequence is used. Look at Step 2 of the AC schematic as you read this.

1. Conditions are like those listed above in #'s 1-7.
2. $\overset{P}{||}$ interlock closes. This keeps a holding circuit for Ⓟ coil.
3. The Pump and Main Control Switch is spring returned to "RUN" position.

   This means the center and bottom contacts of the Pump and Motor Control Switch are open. The circuit works through the closed upper contacts and $\overset{P}{||}$ interlock.

During Steps 3 and 4, special safety features are used. They are explained below. Look at Safety Precautions (Steps 3 and 4) of the AC schematic as you read this.

1. The R_2 relay keeps the main motors from starting by accident. Without this relay with the LA circuit breaker closed and the MA circuit breaker open, the control circuit would energize and close the main motor line starters. If the main

motor switch were in the RUN Position and the MA circuit breaker closed, the Main Motors would start. With R_2 Mercury Switch in the Control Circuit to the main motor line starter will close. Only then will the main motors operate.

2. Keeps machine from starting and shuts down machine if there is a high level of methane gas. This is how it happens. The normally closed "R" contacts of a relay for the methane monitor stay closed at all times except when there are high levels of methane gas. The contacts will open if high levels of gas appear and keep the main motors from starting. This will shut the motors down if they are already running.

To start the Left Main Motor; the following sequence is used. Look at Step 3 of the AC schematic as you read this.

1. All circuit breakers are closed.
2. The operator uses both hands to start the machine. One hand holds the Pump and Main Control Switch in the "RESET" position. The other hand holds the Main Motor Switch in the "RESET" position.
3. When both switches are held in the "RESET" position, the LM coil and the TR coil are energized.
4. When the coils are energized, this completes the circuit

through overloads LM_3, LM_1, RM_3, and RM_1.

5. The Left Main Motor Line Starter closes and the motor starts.

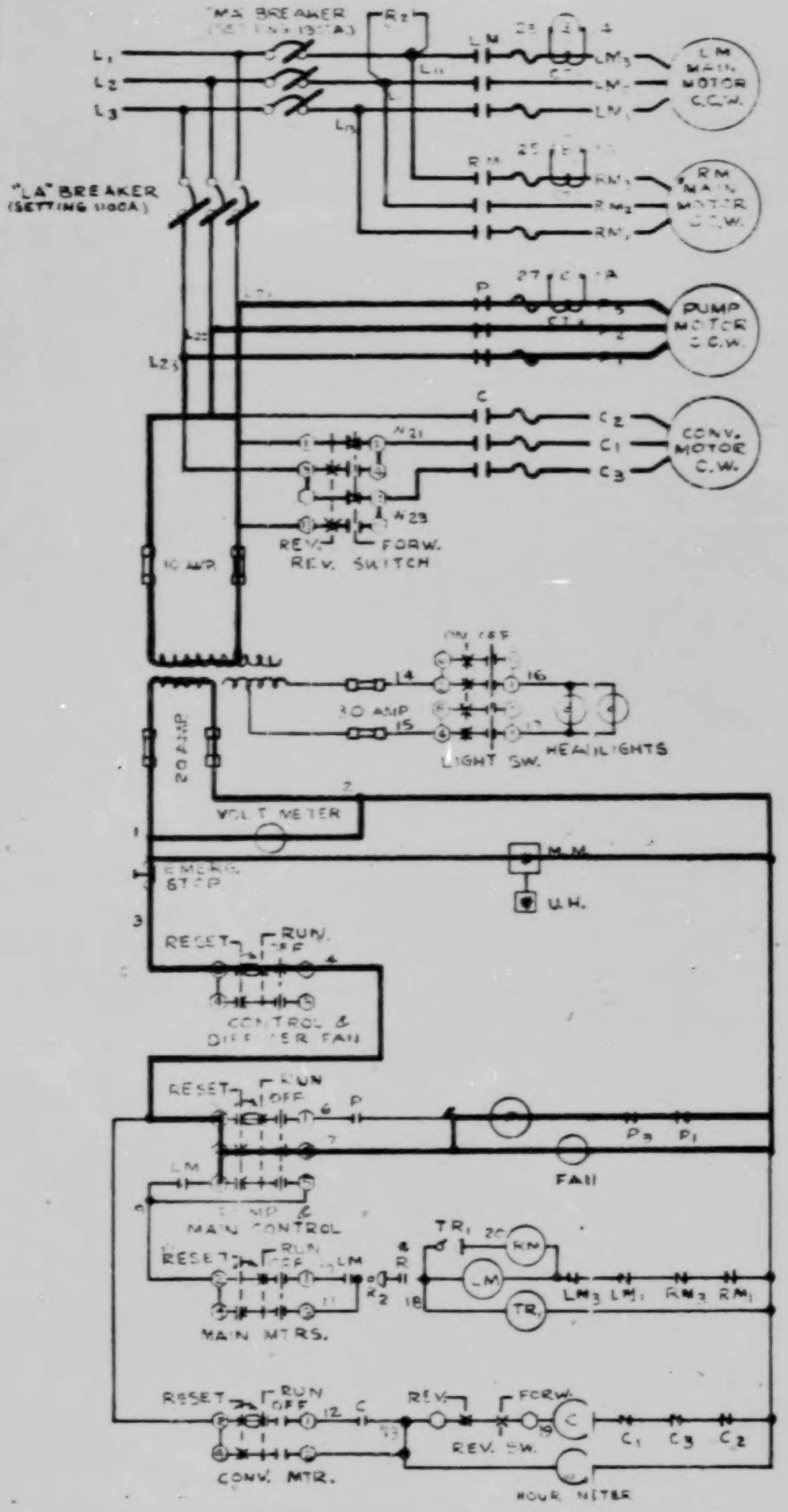
To start the Right Main Motor, the following sequence is used. Look at Step 4 of the AC schematic as you read this.

1. Conditions are like those listed above in #'s 1-5.

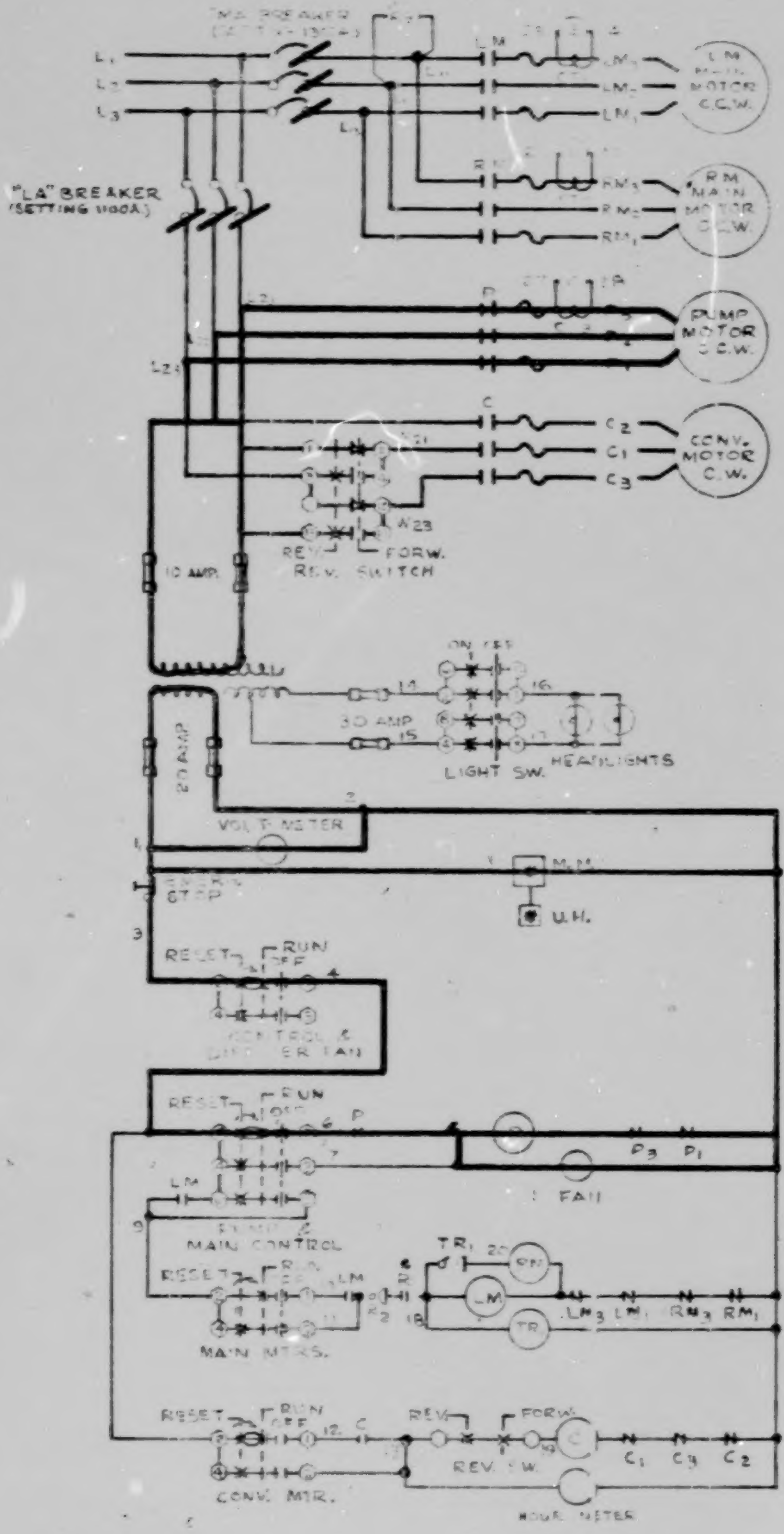
2. Two seconds after the Left Main Motor starts TR_1 coil closes TR_1 Mercury Switch.

3. The RM coil is energized.

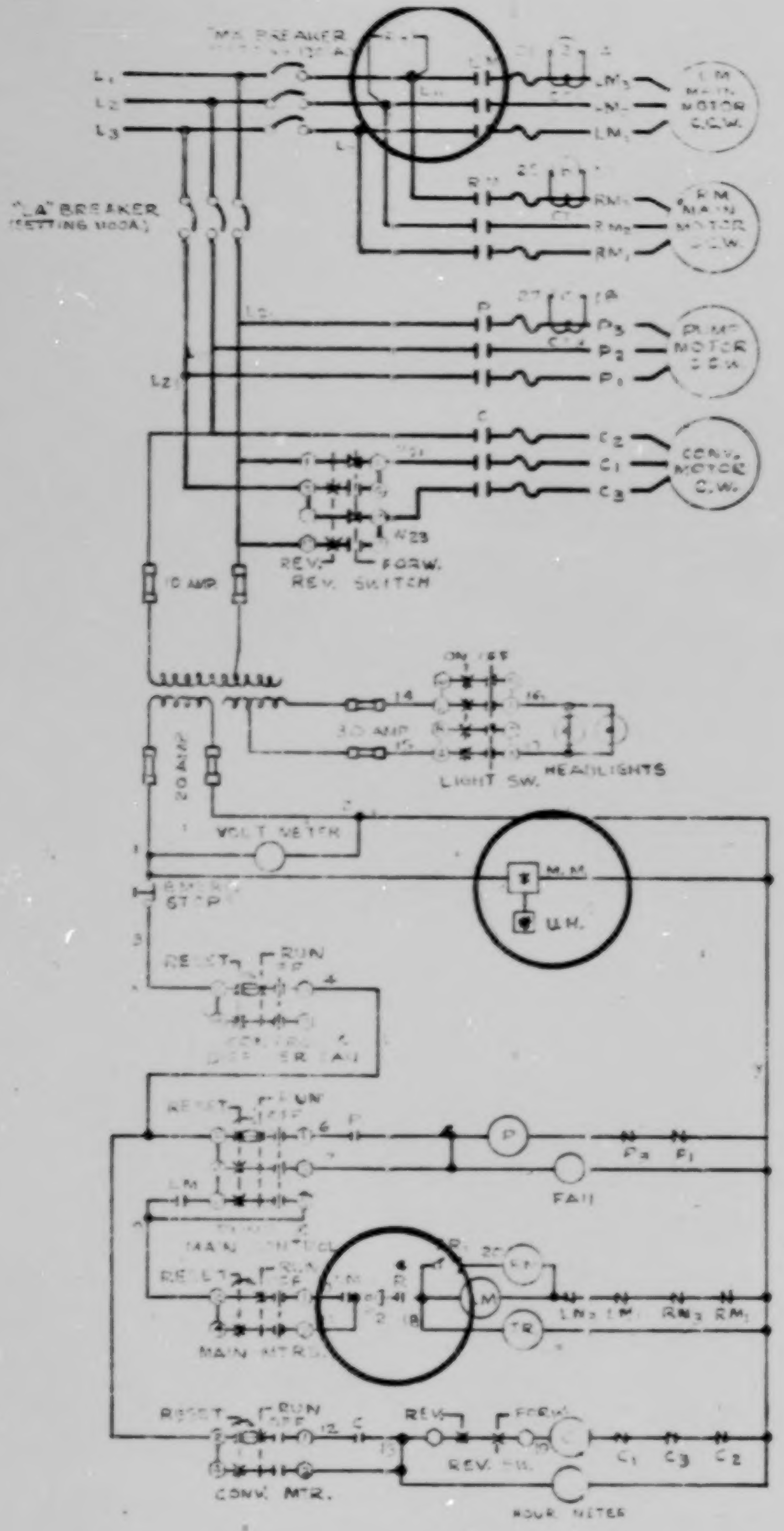
4. The Right Main Motor Line Starter closes and the motor starts.


"MA" BREAKER
(SETTING 1317A)
L1
L2
L3
R2
L11
L13
LM
LM3
LM2
LM1
LM MAIN MOTOR C.C.W.
RM
RM3
RM2
RM1
RM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A)
L21
L22
L23
P
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
N21
N23
REV.
FORW.
REV. SWITCH
10 AMP
ON OFF
14
16
15
17
30 AMP
LIGHT SW.
HEADLIGHTS
20 AMP
2
1
VOLT METER
M.M.
U.H.
EMERG. STOP
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
6
7
P3
P1
FAN
9
PUMP & MAIN CONTROL
TR1
20
RM
LM
R
R2
18
TR1
LM3
LM1
RM3
RM1
MAIN MTRS.
12
13
REV.
FORW.
19
REV. SW.
C1
C3
C2
CONV. MTR.
HOUR METER

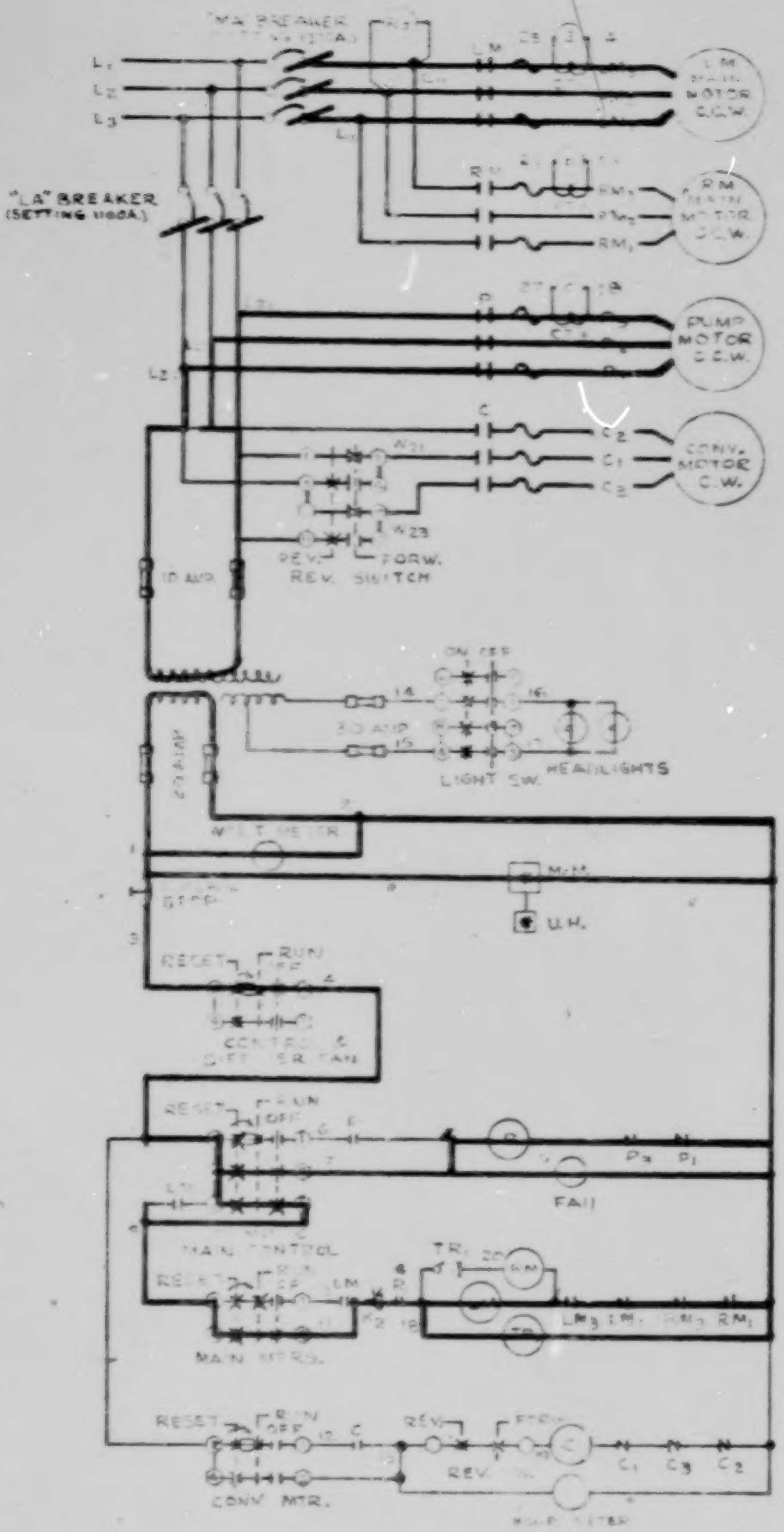
STEP 1


"MA" BREAKER
L1
L2
L3
LM
LM1
LM2
LM3
LM MAIN MOTOR C.C.W.
RM
RM1
RM2
RM3
RM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A)
L21
L23
P
PUMP MOTOR C.C.W.
C
C1
C2
C3
CONV. MOTOR C.W.
W21
W23
REV.
FORW.
REV. SWITCH
10 AMP
ON OFF
14
15
16
17
30 AMP
LIGHT SW.
HEADLIGHTS
20 AMP
2
VOLT METER
1
M.M.
U.H.
EMERG. STOP
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
RESET
RUN
OFF
6
P
7
P3
P1
FAN
LM
9
PUMP & MAIN CONTROL
RESET
RUN
OFF
LM
R
TR1
20
RM
LM
TR
18
LM3
LM1
RM3
RM1
11
MAIN MTRS.
RESET
RUN
OFF
12
C
13
REV
FORW.
19
REV. SW.
C1
C3
C2
CONV. MTR.
HOUR METER

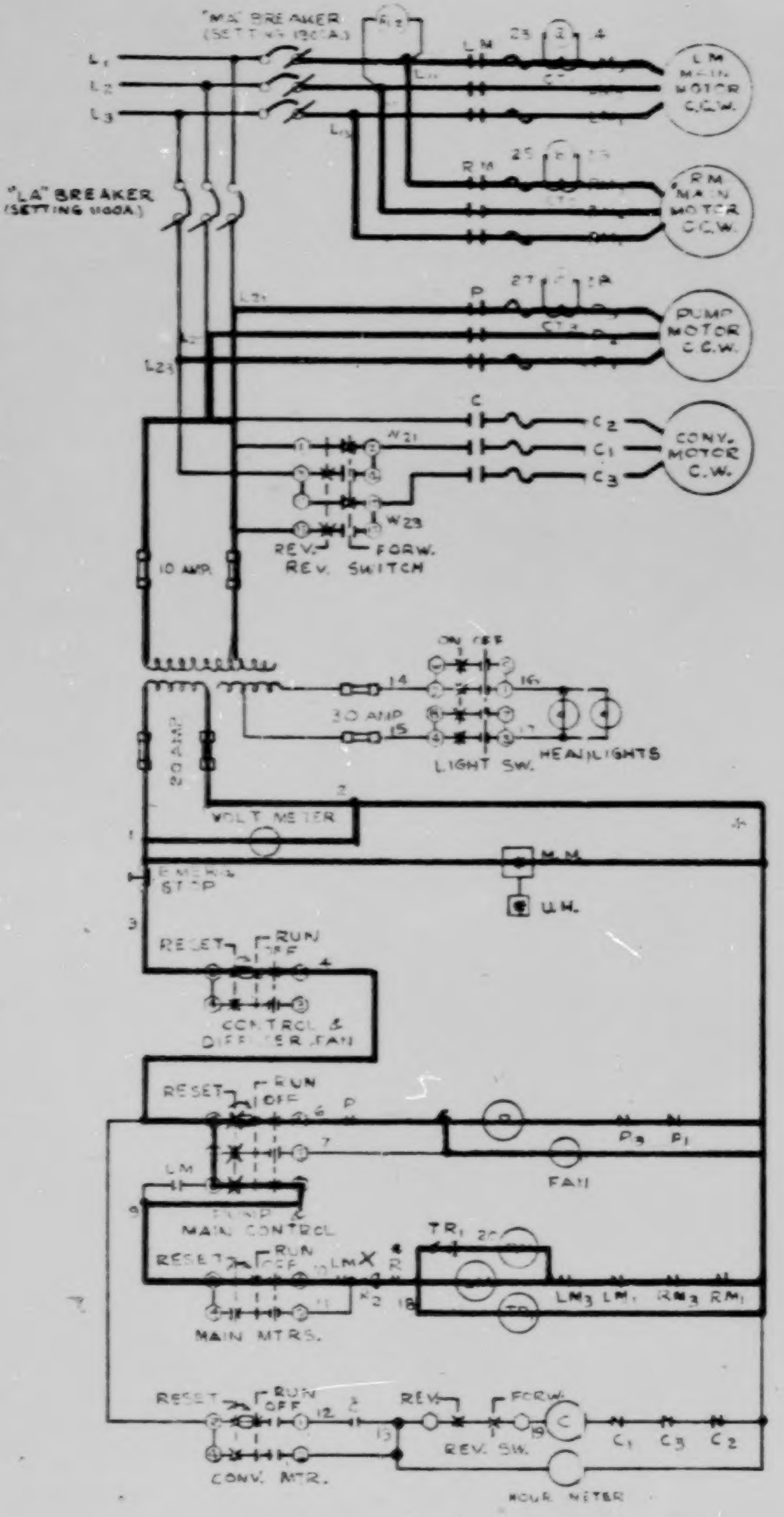
STEP 2


"MA" BREAKER
L1
L2
L3
LM
LM3
LM2
LM1
LM MAIN MOTOR C.C.W.
"LA" BREAKER (SETTING 100A)
RM
RM3
RM2
RM1
RM MAIN MOTOR C.C.W.
P
P3
P2
P1
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
REV.
FORW.
REV. SWITCH
10 AMP
ON OFF
14
16
15
3.0 AMP
LIGHT SW.
HEADLIGHTS
20 AMP
VOLT METER
M.M.
U.M.
EMERG. STOP
RESET
RUN
OFF
4
FAN
MAIN CONTROL
MAIN MTRS.
TR
LM2 LM1 RM2 RM1
P2 P1
12
13
19
REV. SW.
CONV. MTR.
HOUR METER

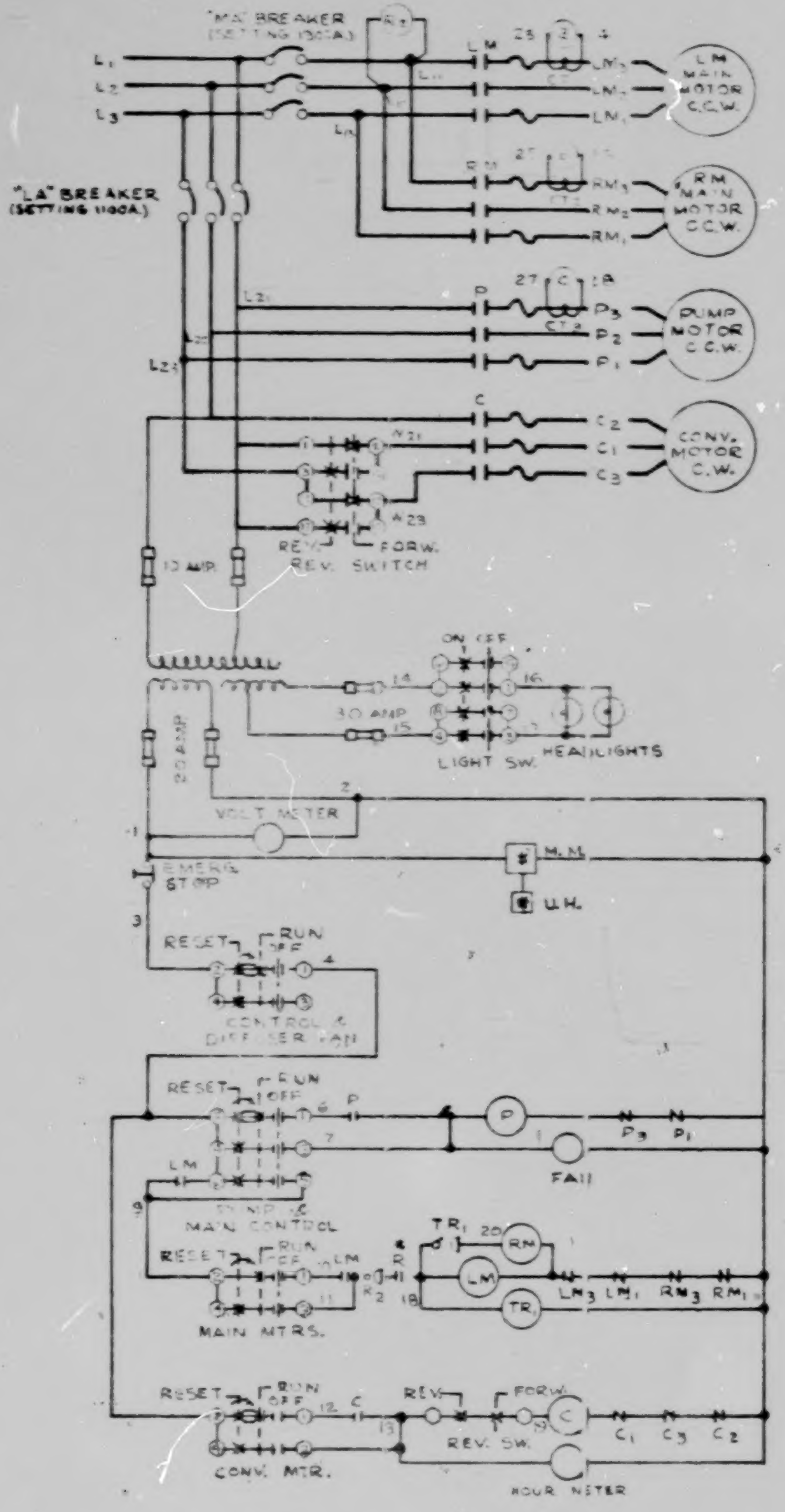
SAFETY PRECAUTIONS (STEPS 3 AND 4)

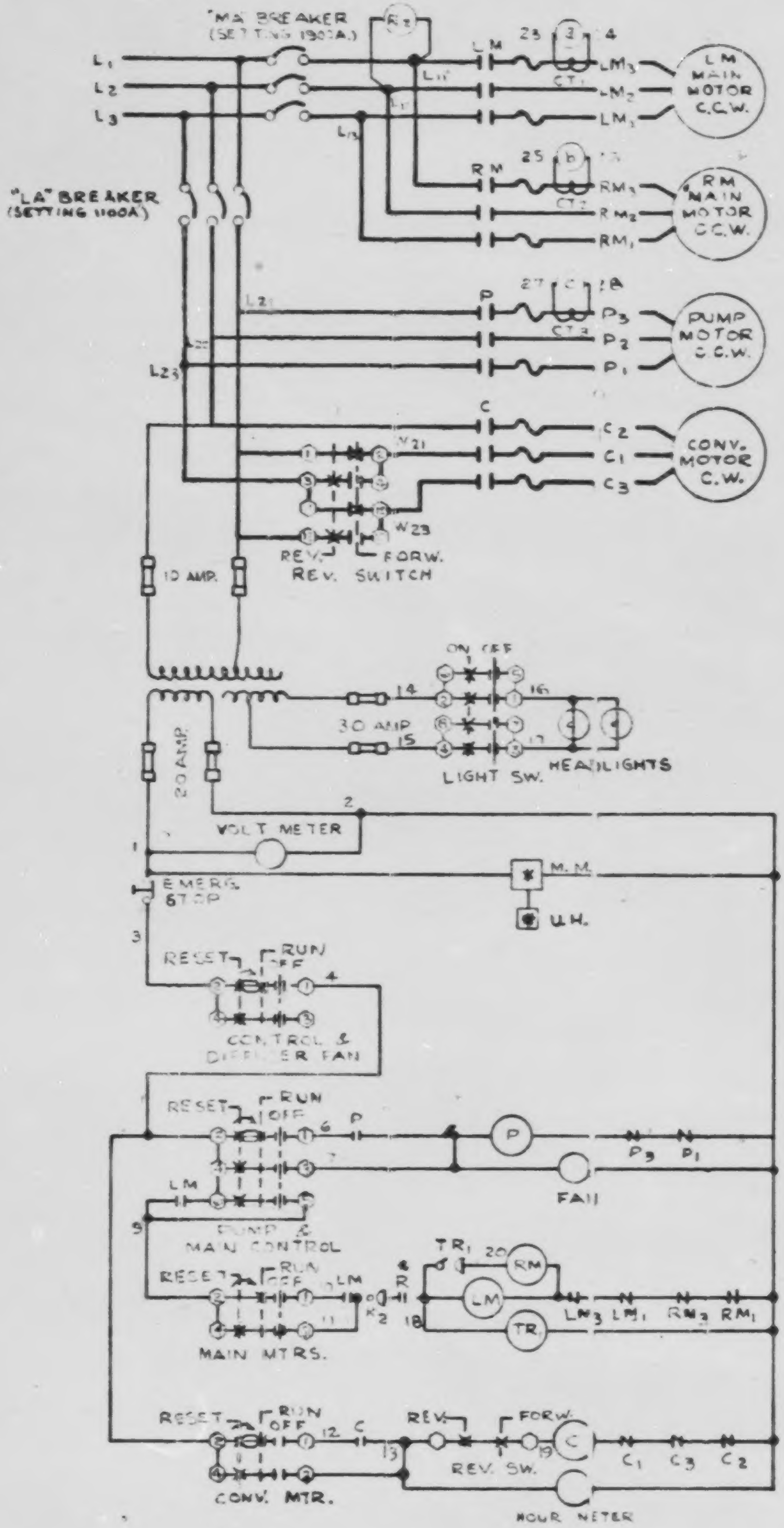

"MA" BREAKER
L1
L2
L3
LM
L.M. MAIN MOTOR C.C.W.
RM
R.M. MAIN MOTOR C.C.W.
RM1
RM2
RM3
"LA" BREAKER (SETTING 1100A.)
P
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
W21
W23
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
15
17
30 AMP.
LIGHT SW.
HEADLIGHTS
VOLT METER
M.M.
U.H.
STOP
RESET
RUN
OFF
CONTROL & DIFFUSER FAN
P3
P1
FAIL
MAIN CONTROL
TR1
RM
LM
TR
LM3
LM1
RM3
RM1
MAIN MTRS.
REV.
FORW.
C1
C3
C2
REV. SW.
CONV. MTR.
HOUR METER

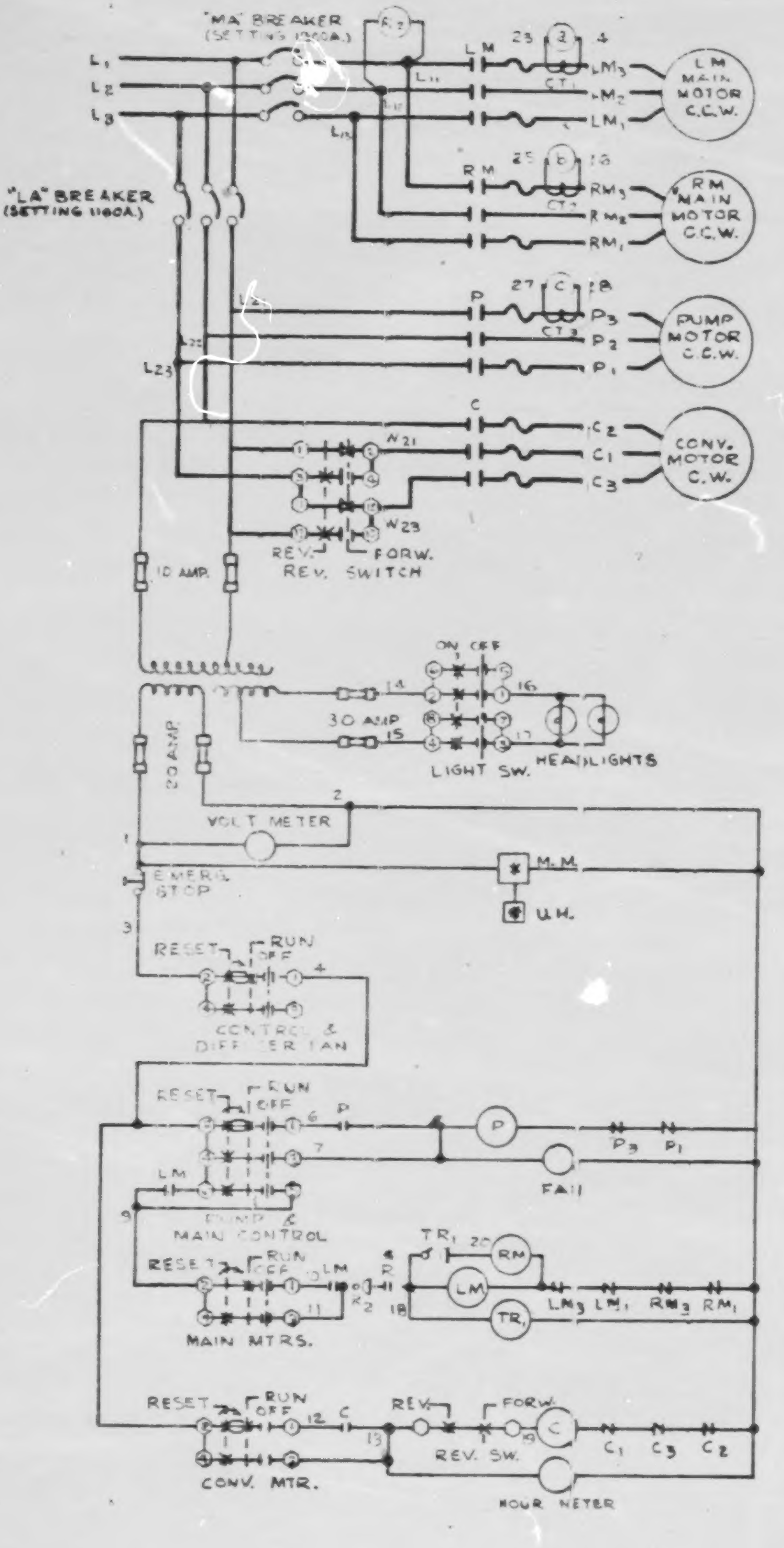
STEP 3


"MA" BREAKER
(SETTING 1300A.)
L1
L2
L3
LM
23
24
LM MAIN MOTOR C.C.W.
RM
25
RM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A.)
L21
L22
L23
P
27
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
W21
W23
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
30 AMP
15
17
LIGHT SW.
HEADLIGHTS
20 AMP
2
VOLT METER
1
M.M.
U.H.
EMERG. STOP
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
RESET
RUN
OFF
6
P
7
FAN
P3
P1
LM
9
PUMP & MAIN CONTROL
TR1
20
RESET
RUN
OFF
10
LMX
11
R2
18
LM3 LM1 RM3 RM1
MAIN MTRS.
RESET
RUN
OFF
12
13
REV.
FORW.
19
C
C1 C3 C2
REV. SW.
CONV. MTR.
HOUR METER

STEP 4


"MA" BREAKER
(SETTING 1300A)
L1
L2
L3
"LA" BREAKER
(SETTING 1100A)
LM
RM
LM MAIN MOTOR C.C.W.
RM MAIN MOTOR C.C.W.
PUMP MOTOR C.C.W.
CONV. MOTOR C.W.
LM3
LM2
LM1
RM3
RM2
RM1
P
P3
P2
P1
C
C2
C1
C3
L21
L22
L23
CT1
CT2
CT3
REV.
FORW.
REV. SWITCH
10 AMP
30 AMP
20 AMP
14
15
16
ON
OFF
LIGHT SW.
HEADLIGHTS
VOLT METER
M.M.
U.H.
EMERG. STOP
1
2
3
4
RESET
RUN
OFF
CONTROL & DIFFUSER FAN
6
7
9
P
FAIL
P3
P1
PUMP & MAIN CONTROL
TR1
20
RM
LM
TR1
R
R2
18
LM3
LM1
RM3
RM1
11
MAIN MTRS.
12
13
C
REV.
FORW.
REV. SW.
C1
C3
C2
CONV. MTR.
HOUR METER


"MA" BREAKER
(SETTING 1900A.)
L1
L2
L3
LM
CT1
LM3
LM2
LM1
LM MAIN MOTOR C.C.W.
RM
CT2
RM3
RM2
RM1
RM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A)
L21
L22
L23
P
CT3
P3
P2
P1
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
W21
W23
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
30 AMP
15
17
LIGHT SW.
HEADLIGHTS
20 AMP.
2
VOLT METER
1
M.M.
U.H.
EMERG. STOP
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
6
P
7
FAIL
P3
P1
LM
9
PUMP & MAIN CONTROL
TR1
20
RM
LM
R
K2
18
TR1
LM3
LM1
RM3
RM1
11
MAIN MTRS.
12
C
13
REV.
FORW.
19
C
C1
C3
C2
REV. SW.
HOUR METER
CONV. MTR.


"MA" BREAKER
(SETTING 1300A.)
L1
L2
L3
L11
L12
L13
LM
LM3
M2
LM1
CT1
LM MAIN MOTOR C.C.W.
RM
RM3
RM2
RM1
CT2
RM MAIN MOTOR C.C.W.
"LA" BREAKER
(SETTING 1100A.)
L21
L22
L23
P
P3
P2
P1
CT3
PUMP MOTOR C.C.W.
C
C2
C1
C3
CONV. MOTOR C.W.
W21
W23
REV.
FORW.
REV. SWITCH
10 AMP.
ON OFF
14
16
30 AMP
15
17
LIGHT SW.
HEADLIGHTS
20 AMP
2
VOLT METER
1
EMERG. STOP
M.M.
U.H.
3
RESET
RUN
OFF
4
CONTROL & DIFFUSER FAN
6
7
P
FAIL
P3
P1
LM
9
PUMP & MAIN CONTROL
TR1
20
RM
10
LM
R2
18
TR1
11
LM3
LM1
RM3
RM1
MAIN MTRS.
12
C
13
REV.
FORW.
19
REV. SW.
C1
C3
C2
HOUR METER
CONV. MTR.

STUDENT COMPETENCY SHEET #1

UNIT: 10 SCHEMATICS: AC/DC-SOLID STATE

COMPETENCY STATEMENT: TRACES PULSE THROUGH AN AC/DC-SOLID STATE SYSTEM AND EXPLAINS OPERATION.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. TRACE WITH A PENCIL THE PULSE FLOW ON AC/DC SOLID STATE SYSTEM DIAGRAMS.
2. EXPLAIN THE OPERATION OF THE SYSTEM YOU TRACE TO THE INSTRUCTOR.

CONDITIONS: YOU HAVE AC/DC-SOLID STATE SYSTEM DIAGRAMS. YOU MAY NOT USE REFERENCES. YOU HAVE 30 MINUTES TO DO THIS.

STANDARD: ALL YOUR TRACING AND EXPLAINING MUST BE CORRECT. THIS MEANS THAT THE SYSTEM REALLY WOULD WORK LIKE YOU SAY.

LEARNING ACTIVITIES:

1. YOUR INSTRUCTOR WILL GIVE A TALK CALLED "TRACING PULSE THROUGH AN AC/DC-SOLID STATE SYSTEM." THE OPERATION OF THE AC/DC-SOLID STATE SYSTEM WILL BE SHOWN DURING THE TALK. GO TO THE TALK.
2. GET STUDENT HANDOUT #1, "TRACING PULSE, AC/DC-SOLID STATE PANEL," FROM THE INSTRUCTOR. READ IT.
3. GET CLEAN COPIES OF THE AC/DC-SOLID STATE SYSTEM DIAGRAMS. TRACE ALL THE STEPS LISTED IN STUDENT HANDOUT #1. AFTER YOU TRACE EACH STEP HAVE THE INSTRUCTOR CHECK YOUR WORK. CHANGE ANYTHING THAT IS WRONG.

4. GET ANOTHER STUDENT AND EXPLAIN WHAT HAPPENS DURING EACH STEP OF OPERATION FOR THE CIRCUITS ON THE AC/DC-SOLID STATE SYSTEM DIAGRAMS.
5. GET THE STUDY QUESTIONS FOR AC/DC-SOLID STATE SYSTEM. ANSWER THE QUESTIONS.
6. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

TRACING PULSE, AC/DC-SOLID STATE PANEL

Unit: 10 Schematics, AC/DC-Solid State

Look at Diagrams #1-#3 as you read this. (If you have WD3536-36 from Joy Manufacturing, do NOT use Diagrams #1-#3.)

Let's start our study of pump and traction circuit operation by saying there is voltage at terminals 1, 5, and 9 of the pump and traction switch (Diagram #2).

Step 1. Pump and Traction Switch is in "Start" position. (Diagram #2)

A. The Switch contact between 9 and 10 closes. The next two contacts to the right are controlled by tram levers. During starting they are closed if the tram levers are in neutral (safety). In other words, the tram levers must be in the "Off" position before the pump motor will start.

B. The contacts between 1 and 2 of the cutter motor switch are closed when the switch is in the "Off" position. (Diagram #2.)

C. We now have a complete current path between 9 and point #3, through the "D" line starter coil, D overload (DOL), and transformer overload (TOL) to line #2. (Diagram #2.)

Step 2. Holding circuit for "D" pump motor.

A. "D" linestarter has now closed D interlock. (Diagram #2.)

B. Switch spring returns switch to the "Run" position. (Diagram #2.)

C. The circuit now completes as follows: from 5 to 6 through now closed "D" interlock to 4 of cutter motor switch; through the jumper wire to 2 of the switch through the "D" coil to DOL and TOL to line #2. (Diagram #2.) Notice the connection at point #8 to the left of "D" coil (Diagram #2). This point will provide power to the conveyor switch as well as to the tram switches. Before going on, see if you can answer this question. What would happen if the Pump and Traction Switch returned to "Run" and the "D" interlock failed to make contact?

Trace the line from "Run" position on the Pump and Traction Switch down to the line connecting 9 and 10 (Diagram #2). Do you see an X? No, the contacts between 9 and 10 are open in the "Run" position. If "D" interlock failed to make contact, the pump motor would have stopped running when the switch was released because "D" coil would have been de-energized. (If you could not answer the question, ask the instructor to explain the switch operation and positions to you.)

When we have the holding circuit just described, the traction switches can be moved to "Forward" or "Reverse" without breaking the circuit to the pump motor. All other switches on the machine can also be operated.

Notice #8 at the top left of Diagram #3. You can see now why we had to first start the pump motor.

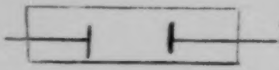
Before we begin to study the logic box, let's look at the power circuit diagram (Diagram #1). We will locate and compare some of the power circuit symbols with their operating components at the right hand side of the logic box in Diagram #3.

1. Transformer, secondary winding (Diagram #1)
   - A. May be either Delta or Wye connected.
   - B. Delta connected when "D1" coil is energized.
   - C. Wye or Star connected when "S1" coil is energized.

   Find coils D1 and S1 at right side of logic box (Diagram #3). Notice the positions of S1 and D1 interlocks. This means that both line starters will not close at the same time.
2. Circuit breaker (3CB) (Diagram #1)
   - A. Closes manually.
   - B. Connects SCR bridge to power source.
3. Bypass contactors (eBR and fBr) (Diagram #1)
   - A. Located in power circuit to the left of each traction motor. All machines are not equipped with this set of contactors.

B. THESE CONTACTORS OPERATE WITH EVERY SPEED CHANGE WHEN SO EQUIPPED.

C. FIND eBR OPERATING COIL AT THE RIGHT SIDE OF LOGIC BOX (DIAGRAM #3).

4. NEW SYMBOL,  STATIC RELAY, TIME DELAY OFF.

A. ALL COMPONENTS ARE IN LOGIC BOX (DIAGRAM #3).

B. THE PURPOSE OF THIS STATIC RELAY IS TO DELAY THE OPENING OF POWER CONTACTS. THE SCR TURNS OFF RAPIDLY. THIS DELAY MAKES SURE THAT NO CURRENT IS FLOWING WHEN THE CONTACTOR DROPS OUT. THIS INCREASES THE LIFE OF THE CONTACT TIPS. IT ALSO LETS US USE THE LIGHTER AC CONTACT TIPS TO CONDUCT DC. THIS IS BECAUSE NO CURRENT WILL BE FLOWING WHEN THEY OPEN AND NO ARCING WILL OCCUR.

THESE STEPS HAVE TO DO WITH LOGIC BOX OPERATION.

STEP 3. DEADMAN SWITCH OPERATION (DIAGRAM #3).

A. LOCATED AT TOP LEFT OF LOGIC BOX NEAR 30 .

B. IT MUST BE CLOSED BEFORE THE MACHINE WILL TRAM.

C. WHEN IT IS CLOSED, IT WILL PICK UP EITHER D1 OR S1. NO CURRENT WILL FLOW UNTIL TRAM LEVERS ARE MOVED TO SOME POSITION.

D. TRANSFORMER POWER CONTACTS ARE CLOSED. THE MOTORS WILL NOT OPERATE UNTIL "E" FORWARD OR "E" REVERSE COIL IS ENERGIZED AND THE SCRs ARE PULSED.

Step 4. D1 Contactor operation

A. Tram levers in "Off" position.

B. Deadman foot switch closed (Diagram #3).

C. Current travels from line #8, through DM switch to 30 of the logic box (Diagram #3).

D. DR (deadman relay) closes, current passes through HSR, DR, S1 interlock to point #2 through D1 coil (Diagram #3).

E. DI contactor closes (Diagram #1). Transformer is in Delta configuration for "Slow" speed (Diagram #1).

The machine will tram in high speed as long as the cutting motors (CMR coil) are not operating (Diagram #2). There are two high speed relay (HSR) contacts in the circuit just traced. One set is closed, the other open (Diagram #3). With the tram lever in "Slow" position, the current flow is just as described.

However, the circuit is different for "Fast" position or high tram. Find HSR (High Speed Relay coil) directly above the Pump and Traction Switch and Cutter Motor Switch. There is a CMR interlock in series with HSR (Diagram #2). When tram levers are in high tram (cutter motors off) this is what happens:

A. HSR coil (Diagram #2) energizes and opens the upper set of HSR contacts (Diagram #3). This closes the lower set of HSR contacts (Diagram #3).

B. D1 CONTACTS DROP OPEN (DIAGRAM #1) AS S1 COIL IS ENERGIZED (DIAGRAM #3). THIS CLOSES S1 CONTACTORS (DIAGRAM #1).

C. THE TRANSFORMER SECONDARY IS NOW WYE OR STAR CONNECTED (DIAGRAM #1).

D. THE MACHINE IS NOW AT MAXIMUM TRAM SPEED. INSTEAD OF GETTING 120 AC VOLTS AND 75-80 DC VOLTS FROM THE TRANSFORMER, WE ARE NOW GETTING 208 AC VOLTS AND ABOUT 275 TO 300 DC VOLTS. (THE DC VOLTAGE IS DUE TO THE SCR BRIDGE.) WITH THE CUTTER MOTORS OPERATING, THE CMR (CUTTING MOTOR RELAY) IS OPEN. THE MACHINE WILL TRAM IN HIGH SPEED AS LONG AS THE CUTTING MOTORS (CMR COIL) ARE NOT OPERATING. THIS WILL LEAVE ONLY THE DELTA CONFIGURATION (LOW VOLTAGE) AVAILABLE FOR TRAMMING. THIS EXPLAINS WHY WE CAN ONLY TRAM AT SLOW SPEED WHILE THE CUTTING MOTORS ARE IN OPERATION.

MANY STEPS ARE LEFT OUT IN ORDER TO ISOLATE THE CIRCUIT FUNCTIONS AROUND THE DEADMAN SWITCH AND TRAM LEVER POSITIONS.

STEP 5. LOCATING POWER INPUT TO SCR FIRING PACKAGE AND PULSE OUTPUT TO SCR BIRDGE.

A. POWER IS PROVIDED TO THE SCR FIRING PACKAGE FROM THE DELTA PRIMARY OF THE MAIN TRANSFORMER.

B. FIND H3, H6, AND H9 AT THE RIGHT HAND BOTTOM OF DIAGRAM #3.

C. FIND THE LINES WITH ARROWS COMING FROM H3, H6, AND H9 FOR THE PRIMARY OF THE MAIN TRANSFORMER (DIAGRAM #1).

D. THESE LINES WILL BE COLOR CODED #12 WIRE. THEY WILL BE CONNECTED TO THE FIRING PACKAGE AS SHOWN (DIAGRAM #3).

E. H3, H6, AND H9 REPRESENT 30, 440 VAC.

STEP 6. CONNECTIONS FROM LOGIC BOX TO FIRING PACKAGE.

A. FIND THE RIGHT SIDE CENTER OF LOGIC BOX (DIAGRAM #3).

B. FIND THE FOLLOWING TERMINALS (DIAGRAM #3);

62 AND 162
63 AND 163
60 AND 160 AND 65

THE TWO DIGIT NUMBERS ARE FOR THE LEFT HAND TRACTION MOTOR CIRCUIT. THE THREE DIGIT NUMBERS ARE THE CORRESPONDING RIGHT HAND TRACTION MOTOR CIRCUIT.

C. FIND THESE SAME NUMBERS AT THE TOP TERMINAL BOARD OF THE FIRING PACKAGE (DIAGRAM #3).

D. THESE CONNECTIONS ARE USED TO SEND CURRENT FROM THE FIRING PACKAGE TO THE LOGIC BOX. RETURN CURRENT FROM THE LOGIC BOX TO FIRING PACKAGE IS THROUGH LINE 65.

E. IN ORDER TO DO THIS, L1R AND L2R MUST BE CLOSED. THIS IS SO THE SCRS DO NOT FIRE (DIAGRAM #3).

F. THE CONNECTIONS FROM THE LOGIC BOX "TELL" THE FIRING PACKAGE "WHEN" TO FIRE THE SCR AND PULSE RATE TO USE.

AS WE ARE GOING TO CONCERN OURSELVES WITH THE LEFT HAND TRACTION CIRCUIT ONLY, CAN YOU PICK OUT THE TERMINALS ON THE LOGIC BOX THAT WE WILL CONCERN OURSELVES WITH?

YOU SHOULD HAVE CHOSEN 60 (D1), 62 (E SLOW), AND 63 (E FAST) AND OF COURSE, 65 (DIAGRAM #3). THIS IS THE RETURN LINE TO THE FIRING PACKAGE.

Let's talk about the logic box and firing package in a little more detail. In earlier lessons, we talked about RC, RL, and RLC circuits. These are what these two packages are mostly made up of. In addition, each has a diode bridge to convert the 120 AC and 440 AC to a very low DC voltage. We need this because we cannot apply these high voltages to solid state components. Remember, these are just signaling devices that send out small pulses. You might think of them as an operating circuit within an operating circuit. The firing package converts its 440 AC volts to about 24 DC volts. The logic box converts its 120 AC volts to about 9 DC volts. The operating coils, which close the contactors, still receive 120 AC volts for their operation.

Most of the circuits that we talk about from this point on are hidden inside their boxes. We will discuss their function, but we are mainly interested in the voltage at the terminals of these boxes. The voltage readings will help us decide if one of these packages is to be replaced. This is what has happened so far:

A. Pump and Traction Switch is in "Run" position (Diagram #2).
B. We have 120 AC volts at ⑧ (Diagram #3).
C. Footswitch (Deadman) closed (Diagram #3).
D. D1 contactor closed (transformer in Delta) (Diagram #1).
E. 440 AC volts to firing package.

Step 7. Left hand traction switch to "Slow" position.

  A. Input voltage to ⑩ (Diagram #3).
  B. eFR solid state switch closes, completing the circuit to ⑪ and to the e Forward coil (Diagram #3).

C. FORWARD CONTACTS, LEFT HAND TRACTION MOTOR CLOSE (DIAGRAM #1).

D. TWO MORE THINGS HAPPEN WHEN THE E FOR. COIL WAS ENERGIZED. FORWARD INTERLOCK, IN SERIES WITH THE COIL, OPENED (PREVENTS REVERSE COIL FROM ENERGIZING) (DIAGRAM #3).

E. ANOTHER EFR CONTACT JUST OFF 40 WHICH IS IN SERIES WITH L2R COIL, CLOSES (DIAGRAM #3).

(DO NOT ASSUME CURRENT FLOW THROUGH THIS POINT YET.)

F. NOW, A SIGNAL WILL BE SENT FROM THE FUNCTION BLOCK (WHICH IS THE LARGE SQUARE BLOCK BETWEEN 30 AND 40) TO THE L1R COIL, COMPLETING THE CIRCUIT TO 2 (DIAGRAM #3).

G. L1R RELAY ⊣ ⊢ OPENS (DIAGRAM #3).

H. SIGNAL IS SENT TO FIRING PACKAGE FROM LOGIC BOX.

I. VOLTAGE BETWEEN 62 AND 65 SHOULD READ ABOUT 14 DC VOLTS.

J. MACHINE BEGINNING TO MOVE FORWARD.

AT THIS POINT, THERE ARE 80 DC VOLTS APPLIED TO THE TRACTION MOTOR.

NOW, LET'S BACK UP A BIT AND SEE JUST HOW THIS FIRING OF THE SCR OCCURRED. THE L1R AND L2R RELAYS ARE CLOSED. CURRENT TRAVELS FROM 62 AND 63 OF THE FIRING PACKAGE TO 62 AND 63 OF THE LOGIC BOX. THE CURRENT CONTINUES THROUGH CLOSED L1R AND L2R TO 65 AND RETURNS TO THE FIRING PACKAGE 65. IT BY-PASSES THE SCR BRIDGE CIRCUIT (DIAGRAM #3). PICTURE THE CURRENT AS GOING IN A CIRCLE AT THIS TIME, DOING NOTHING. IT'S JUST TAKING THE PATH OF LEAST RESISTANCE.

Now, when L1R opens, this part of the current will go to 1 - 6. These terminals are connected to the gates of the SCR bridge of the left hand traction motor. The SCR will now conduct. The machine will move.

What happens when pulse rate increases? The SCR conducts even more. Well then, when L2R opens, with increased pulse rate going to the SCR gate, conduction takes place.

Be certain that you understand all previous events to this point before continuing. If in doubt, ask.

Let's take just a moment and discuss machines that are equipped with series starting resistance.

Remember, when L1R coil energized, it closed a set of L1P contacts in series with the eBR coil at 48 on the right side of logic box (Diagram #3). Notice that the eBR function switch is a "TD on" type switch (Diagram #3). One second after L1R coil energized, the eBR function switch closed and energized the eBR coil (Diagram #3). This closed the eBR contacts in the traction circuit (Diagram #1). This shorted out the series starting resistor, resulting in a slight increase in speed. The timing of the eBR switch is such that no jolt or jar is felt when these contacts are closed.

Step 8. Left hand traction switch to "Fast" position (Diagram #3).

A. Voltage at 40 of logic box.

B. The eBR interlock is now closed.

C. L2R coil is energized. L2R relay opens. This results in more current going to the SCR bridge and further increases speed.

D. Notice the current path through the CMR NC switch (Diagram #3). Would the machine go into high speed if the CMR coil were energized? As you can see, if the CMR coil were energized, these contacts would be open. The circuit would not be complete to the L2R coil. The machine would not go into the second or high fast tram speed.

Points to Remember:

A. Pump and Traction Switch must be in the "Run" position to complete a circuit to 8 of the logic box (Diagrams #2 and #3).

B. The "Run" position of the Pump and Traction Switch limit our speeds to these two speeds:

1. Tram lever in first, or low slow position, L1R opens; voltage at SCR bridge = 80 DC volts.
2. Tram lever in second or low fast position, L2R opens; voltage at SCR bridge = 160 DC volts.

C. The voltage at the SCR bridge is the maximum voltage available in the second or low fast tram position when the transformer secondary is Delta connected.

D. The SCR firing package converts its 440 AC volt input to 24 DC volts.

E. The logic box converts its 120 AC volts to about 9 DC volts.

F. The footswitch must be turned on first before the tram levers.

G. The L1R and L2R relays must open in order for the firing package to pulse the SCR bridge (Diagram #3).

H. 60, 62, and 63 of the firing package send current to the logic box 60, 62, and 63 (Diagram #3).

I. That current circulates, or does nothing but returns to the firing package on line 65.

J. Current to line 65 is interrupted by L1R and L2R, of the logic box. This same "circulating" current is then directed to the gates of the SCR bridge. It turns them "On" thru 1 - 6 on the firing package (Diagram #3)

There are two more speeds available to us on this machine by changing the transformer from Delta to Wye or Star connected. The Pump switch must be in "Fast" position (Diagram #2). The current flows from 1 to point 2, to 80 (Diagram #2, to NC CMR relay, HSR coil (High speed relay) to 2 (Diagram #2). The cutter motors are off.

Step 9. Logic Circuit, High speed (Diagram #3).

A. Tram lever in "Off" position.

B. Footswitch closed (Diagram #3).

C. Current now flows through NC CMR contact, HSR contact, SR switch, 47 of the logic box, D1 interlock, S1 coil to point 2 (Diagram #3).

D. The S1 coil energizes opening S1 interlock to D1 coil (Diagram #3).

E. D1 interlocks at 60 and 160 open (Diagram #3). This "tells" the firing package that the "Fast" speed has been selected.

F. S1 contactor closes. This connects the secondary of the power transformer in Wye configuration (Diagram #1).

Step 10. Tram Lever to "High Slow" position.

A. Input signal to EFR relay (Diagram #3). FFor. coil closes forward contacts (Diagram #3).

B. Input signal also goes to the function block (Diagram #3).

C. Function block sends signal to L1R coil and L1R opens. The SCR bridge is turned on (Diagram #3). The DC voltage at the SCR bridge will be about 150 DC volts with L1R open.

D. When the L1R coil was energized, another set of L1R contacts (across from 40) closed (Diagram #3). No current will flow through this point yet until we move to the "High Fast" position.

Step 11. Tram lever to "High Fast" position.

A. Tram lever to second position "signals" L2R coil

AND L2R CONTACTS TO OPEN (DIAGRAM #3).

B. MORE GATE CURRENT IS APPLIED TO THE SCR BRIDGE.

C. DC VOLTAGE AT THE BRIDGE IS NOW ABOUT 275 TO 300 DC VOLTS. WE HAVE MAXIMUM TRAM SPEED.

STEP 12. MACHINE OFF.

RELEASING THE TRAM LEVERS, RETURNS THEM TO THE "OFF" POSITION.

A. L1R AND L2R RELAYS CLOSE (DIAGRAM #3).

B. SCR BRIDGE SHUTS OFF (DIAGRAM #3).

C. SR SWITCH TIMES OUT (1 SECOND) (DIAGRAM #3).

D. eFR SWITCH TIMES OUT (1 SECOND) (DIAGRAM #3).

E. S1 CONTACTS AND e FORWARD CONTACTS DROP OPEN. (DIAGRAM #1.)

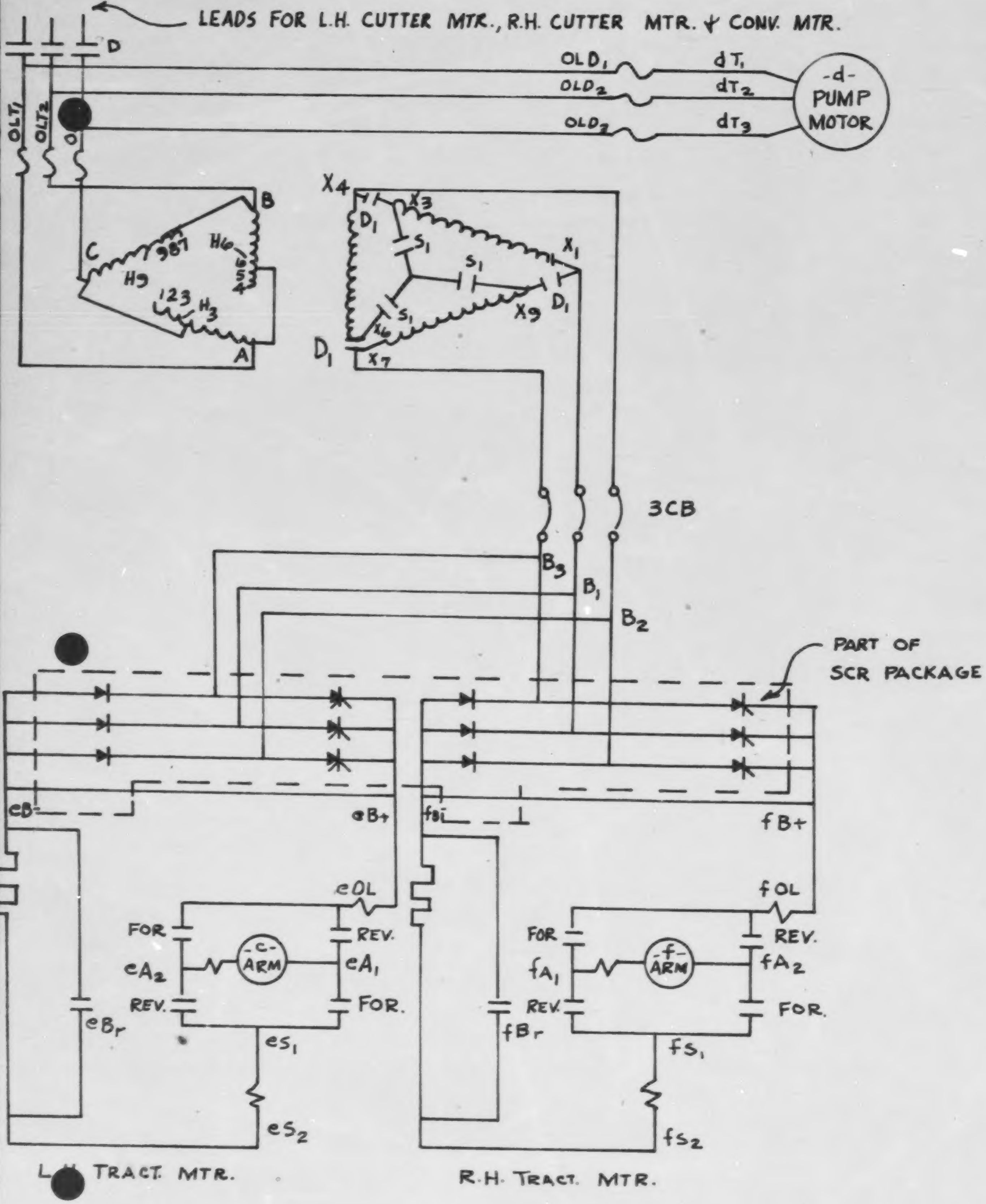

LEADS FOR L.H. CUTTER MTR., R.H. CUTTER MTR. & CONV. MTR.
D
OLD₁
OLD₂
OLD₃
dT₁
dT₂
dT₃
-d- PUMP MOTOR
OLT₁
OLT₂
O
B
C
987
H6
6
5
4
H9
123
H₃
A
X4
X3
D₁
S₁
S₁
X₁
S₁
X6
X9
D₁
D₁
X₇
3CB
B₃
B₁
B₂
PART OF SCR PACKAGE
eB-
eB+
fBi
fB+
eOL
fOL
FOR.
REV.
-c- ARM
eA₂
eA₁
REV.
FOR.
eBr
eS₁
eS₂
FOR.
REV.
-f- ARM
fA₁
fA₂
REV.
FOR.
fBr
fS₁
fS₂
L.H. TRACT. MTR.
R.H. TRACT. MTR.

DIAGRAM 1

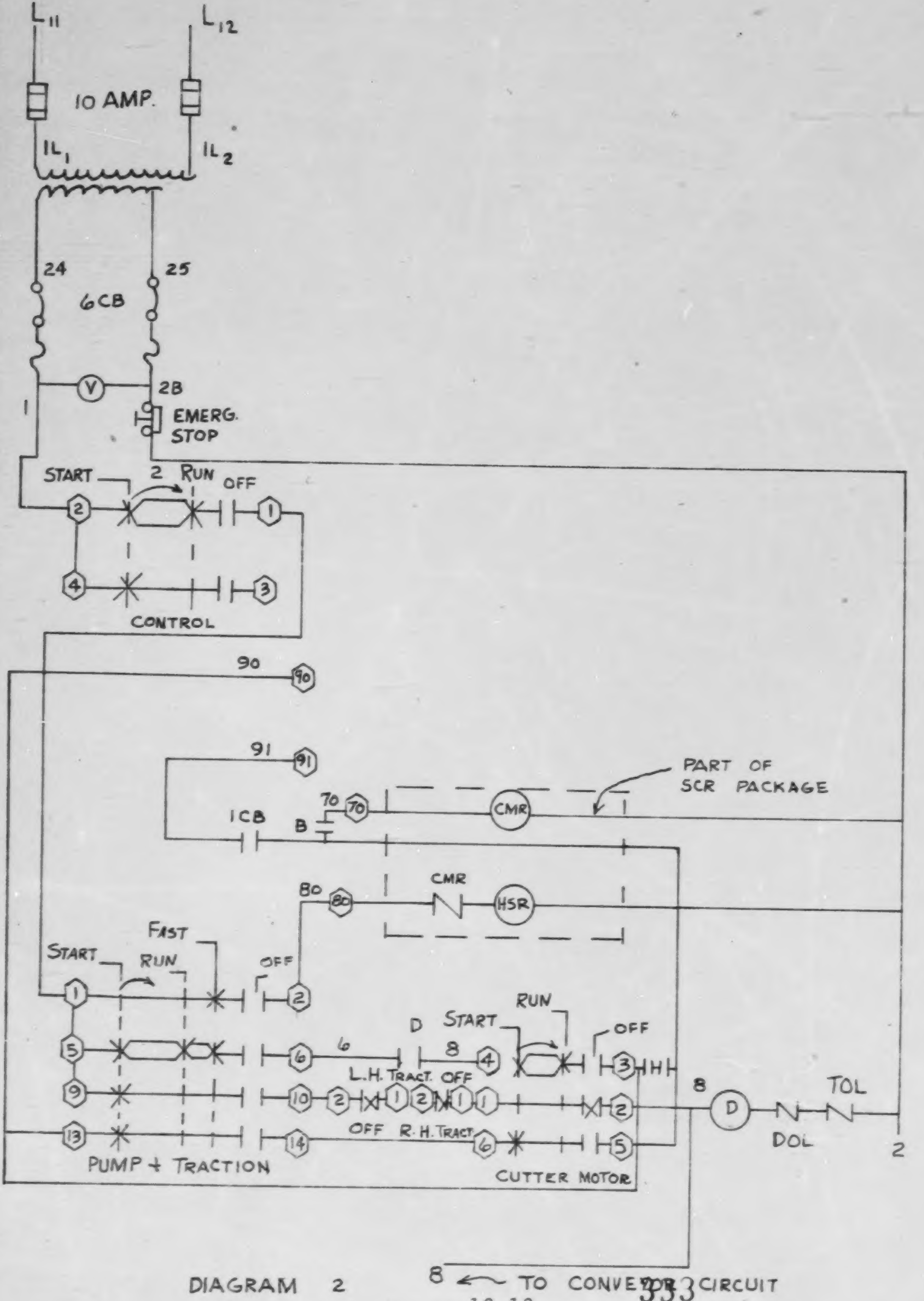

L11
L12
10 AMP.
1L1
1L2
24
25
6CB
1
V
2B
EMERG. STOP
START
2
RUN
OFF
2
1
4
3
CONTROL
90
90
91
91
PART OF SCR PACKAGE
70
70
CMR
1CB
B
80
80
CMR
HSR
FAST
START
RUN
OFF
1
2
5
6
6
D
8
4
START
RUN
OFF
3
L.H. TRACT. OFF
9
10
2
1
2
1
1
2
8
D
TOL
DOL
2
13
14
OFF R.H. TRACT.
6
5
PUMP + TRACTION
CUTTER MOTOR
8 ← TO CONVEYOR CIRCUIT

DIAGRAM 2

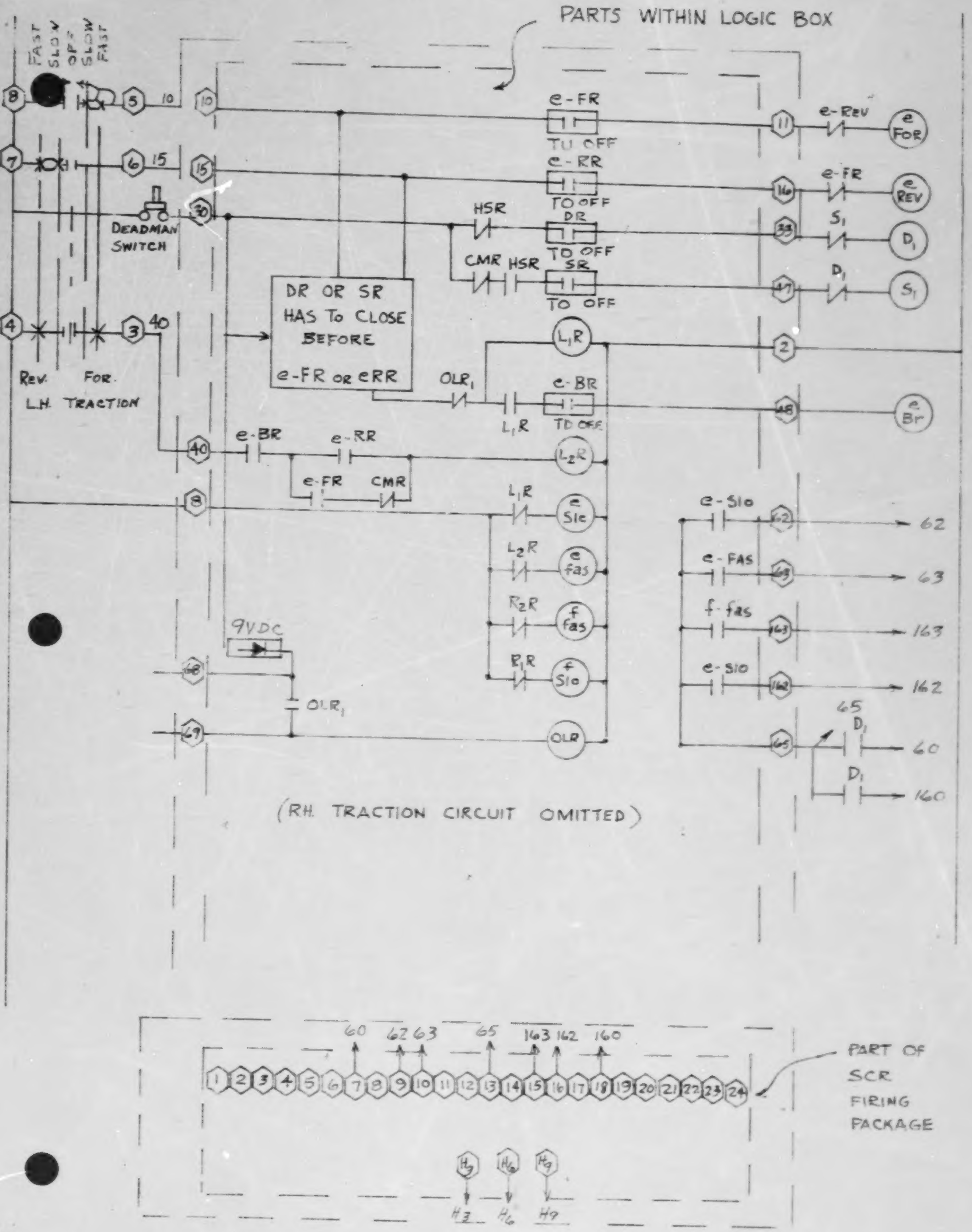

PARTS WITHIN LOGIC BOX
FAST
SLOW
OFF
SLOW
FAST
8
5
10
7
6
15
DEADMAN SWITCH
30
4
3
40
REV.
FOR.
L.H. TRACTION
e-FR
TD OFF
e-RR
TD OFF
HSR
DR
TD OFF
CMR
HSR
SR
TD OFF
DR OR SR HAS TO CLOSE BEFORE e-FR OR eRR
L1R
OLR1
e-BR
TD OFF
L1R
e-BR
e-RR
L2R
e-FR
CMR
L1R
e Slo
L2R
e fas
R2R
f fas
R1R
f Slo
9VDC
OLR1
48
49
OLR
11
e-REV
e FOR
16
e-FR
e REV
33
S1
D1
47
D1
S1
2
48
e Br
e-Slo
62
e-FAS
63
f-fas
163
e-Slo
162
65
D1
60
D1
160
(RH. TRACTION CIRCUIT OMITTED)
60
62
63
65
163
162
160
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
PART OF SCR FIRING PACKAGE
H3
H6
H9
H3
H6
H9

DIAGRAM 3

STUDY QUESTIONS
AC/DC-SOLID STATE SYSTEM

UNIT: 10 SCHEMATICS, AC/DC-SOLID STATE

INSTRUCTIONS: READ THE WHOLE QUESTION AND ALL ITS PARTS BEFORE DOING ANYTHING.

1. TRACE OUT THE PUMP AND TRACTION CIRCUIT ON DIAGRAM #2.
   - A. BEGIN AT THE TRANSFORMER SECONDARY.
   - B. USE THE RED PENCIL PROVIDED.
   - C. CIRCLE THE WORD THAT TELLS WHAT POSITION THE SWITCH IS IN.
   - D. USE A SHORT, DASHED LINE TO SHOW THE HOLDING CIRCUIT.
   - E. WHERE THE HOLDING CIRCUIT JOINS OR IS ON THE SAME CONDUCTOR, SHOW THIS BY DASHED LINES ALONGSIDE THE CONDUCTOR.

2. WHAT PURPOSE DOES THE "D" INTERLOCK PROVIDE?

3. ONE OF THE TRAM LEVERS IS IN THE "SLOW" POSITION. HOW WOULD THIS AFFECT STARTING THE PUMP MOTOR?

4. IN WHAT POSITION IS THE CENTER CONTACT OF THE CUTTER MOTOR SWITCH WHEN THAT SWITCH IS OFF?

5. NAME TWO FUNCTIONS PROVIDED BY THE "D" CONTACTOR.

6. ON DIAGRAM #2; CIRCLE THE SYMBOLS THAT PROTECT THE "D" PUMP MOTOR AND THE MAIN TRANSFORMER.

7. ON DIAGRAM #3, WITH THE FOOTSWITCH (DEADMAN) CLOSED, CIRCLE ALL THE COMPONENTS THAT WILL BE ENERGIZED. (THE PUMP MOTOR IS RUNNING.)

8. USING DIAGRAM #1, CIRCLE ANY COMPONENTS THERE THAT ARE ENERGIZED BY THE FOOTSWITCH.

9. REFERRING TO DIAGRAM #3; CLOSE THE FOOTSWITCH AND PLACE THE TRAM CONTROL IN THE SLOW POSITION. DRAW A SQUARE AROUND ALL COMPONENTS THAT ARE ENERGIZED.

10. ON DIAGRAM #3, TRACE OUT THE CIRCUIT, CONNECTING THE POINTS THAT YOU HAVE JUST DRAWN THE SQUARE AROUND.

11. USING DIAGRAM #1, CIRCLE THE COMPONENTS THAT WERE AFFECTED WHEN THE TRAM LEVER WAS PLACED IN THE SLOW POSITION.

12. ON DIAGRAM #3, MOVE THE TRAM LEVER TO THE SECOND POSITION, AND "X" THE COMPONENTS AFFECTED.

13. WHAT WOULD HAPPEN IF THE L2R RELAY WOULD NOT OPEN?

14. ON DIAGRAM #2, PLACE THE PUMP AND TRACTION SWITCH IN THE "FAST" POSITION AND TRACE THE RESULTING CIRCUIT.

15. WITH THE FOOTSWITCH CLOSED AND THE TRAM LEVER IN "FAST" POSITION (DIAGRAM #3), MARK AN * ABOVE EACH COMPONENT THAT IS NOW IN THE CIRCUIT.

16. WOULD THERE BE ANY CURRENT FLOW IN LINE 65 TO THE FIRING PACKAGE WITH JUST THE L1R RELAY OPEN? WHY?

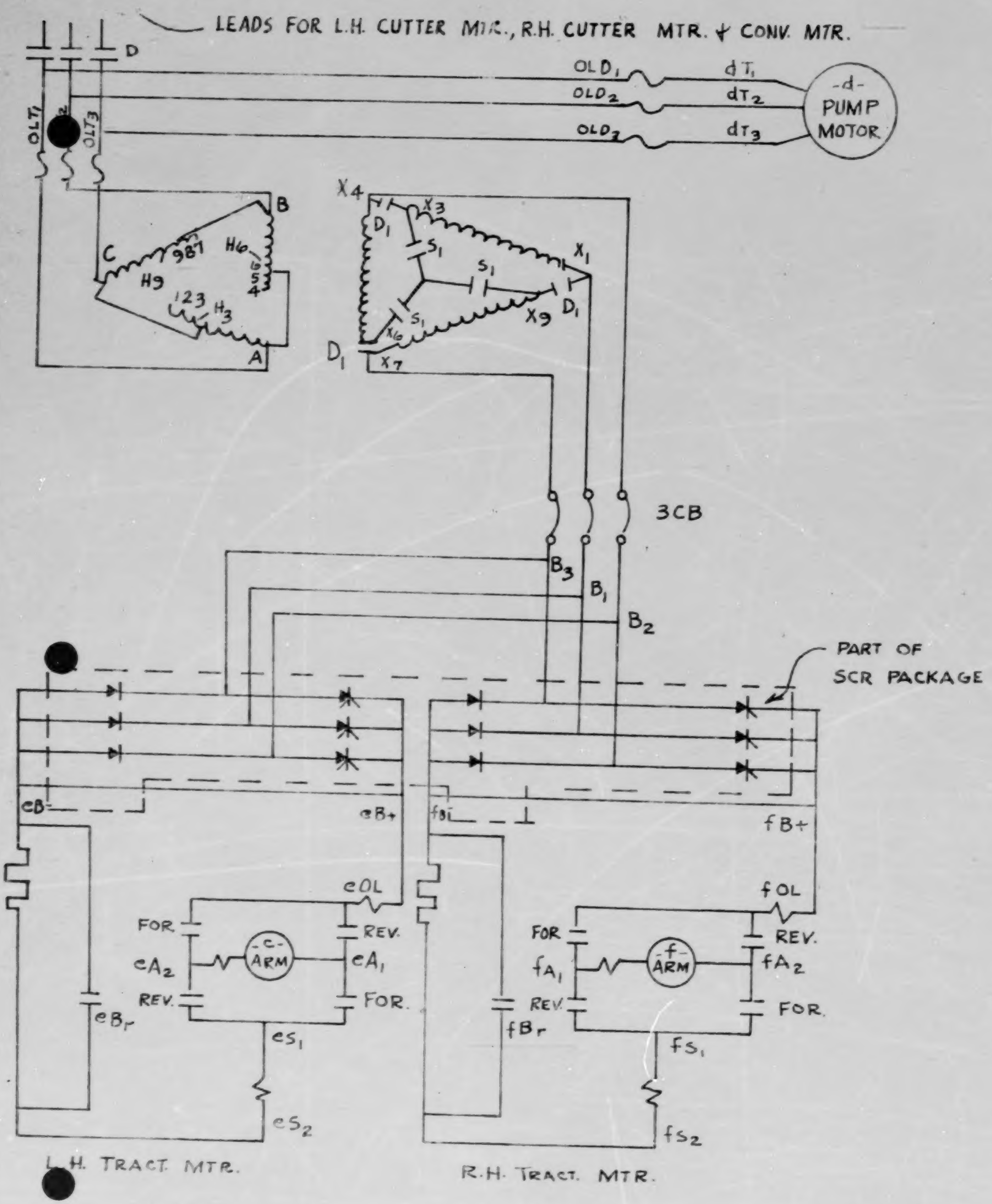
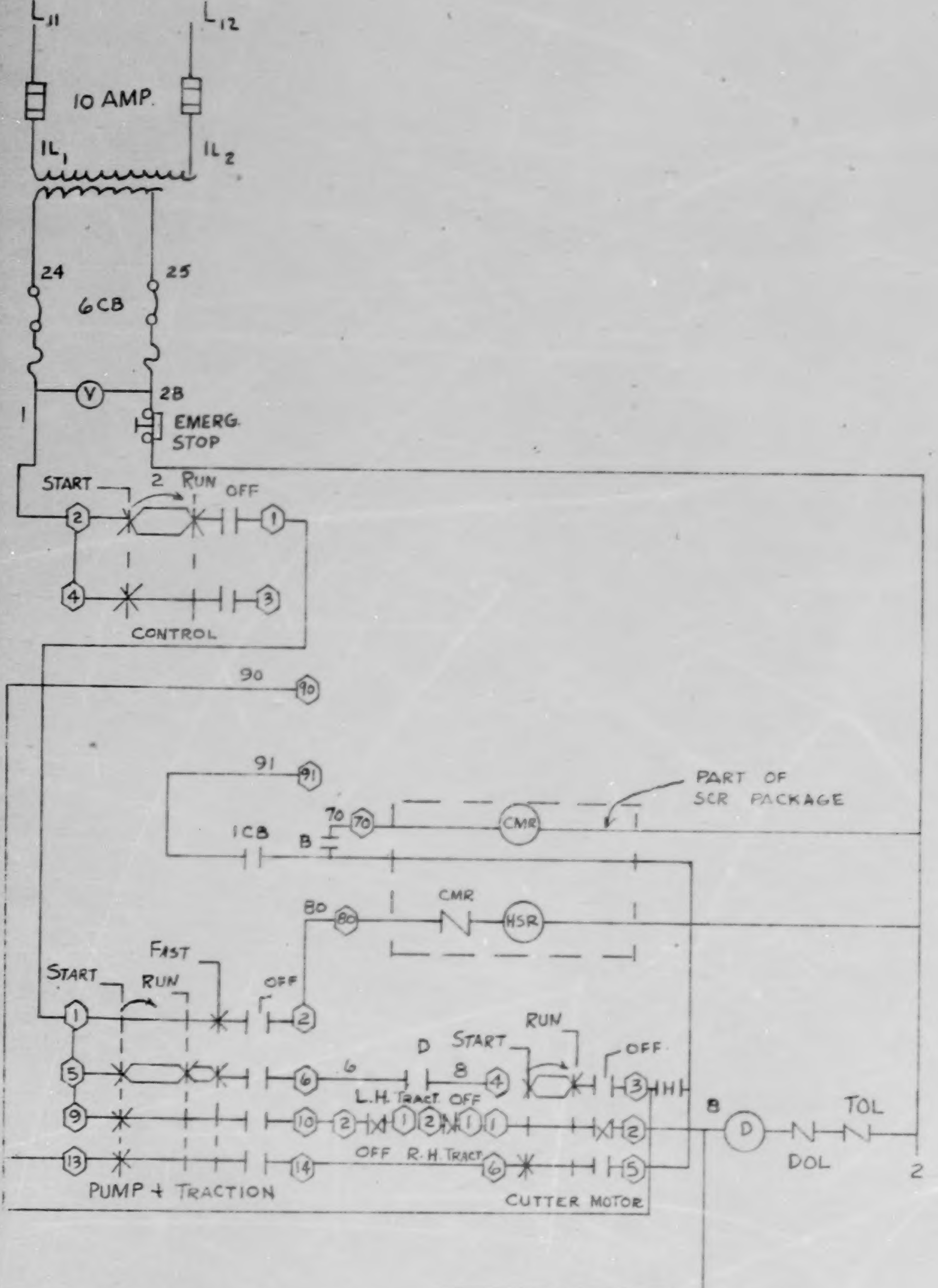

LEADS FOR L.H. CUTTER MTR., R.H. CUTTER MTR. & CONV. MTR.
D
OLD1
OLD2
OLD3
dT1
dT2
dT3
-d- PUMP MOTOR
OLT1
OLT2
OLT3
B
C
A
987
H6
6
5
4
H9
123
H3
X4
X3
D1
S1
S1
X1
D1
X9
S1
X6
D1
X7
3CB
B3
B1
B2
PART OF SCR PACKAGE
eB-
eB+
fB-
fB+
eOL
FOR
REV.
eA2
-c- ARM
eA1
REV.
FOR.
eBr
eS1
eS2
fOL
FOR
REV.
fA1
-f- ARM
fA2
REV.
FOR.
fBr
fS1
fS2
L.H. TRACT. MTR.
R.H. TRACT. MTR.

DIAGRAM 1

10-22


L11
L12
10 AMP.
1L1
1L2
24
25
6CB
1
V
28
EMERG. STOP
START
2
RUN
OFF
1
2
3
4
CONTROL
90
91
70
PART OF SCR PACKAGE
1CB
B
CMR
80
CMR
HSR
FAST
START
RUN
OFF
1
2
5
6
9
10
13
14
D
6
8
START
RUN
OFF
4
3
L.H. TRACT. OFF
OFF R.H. TRACT.
5
PUMP + TRACTION
CUTTER MOTOR
8
D
DOL
TOL
2

8 ← TO CONVEYOR CIRCUIT

DIAGRAM 2

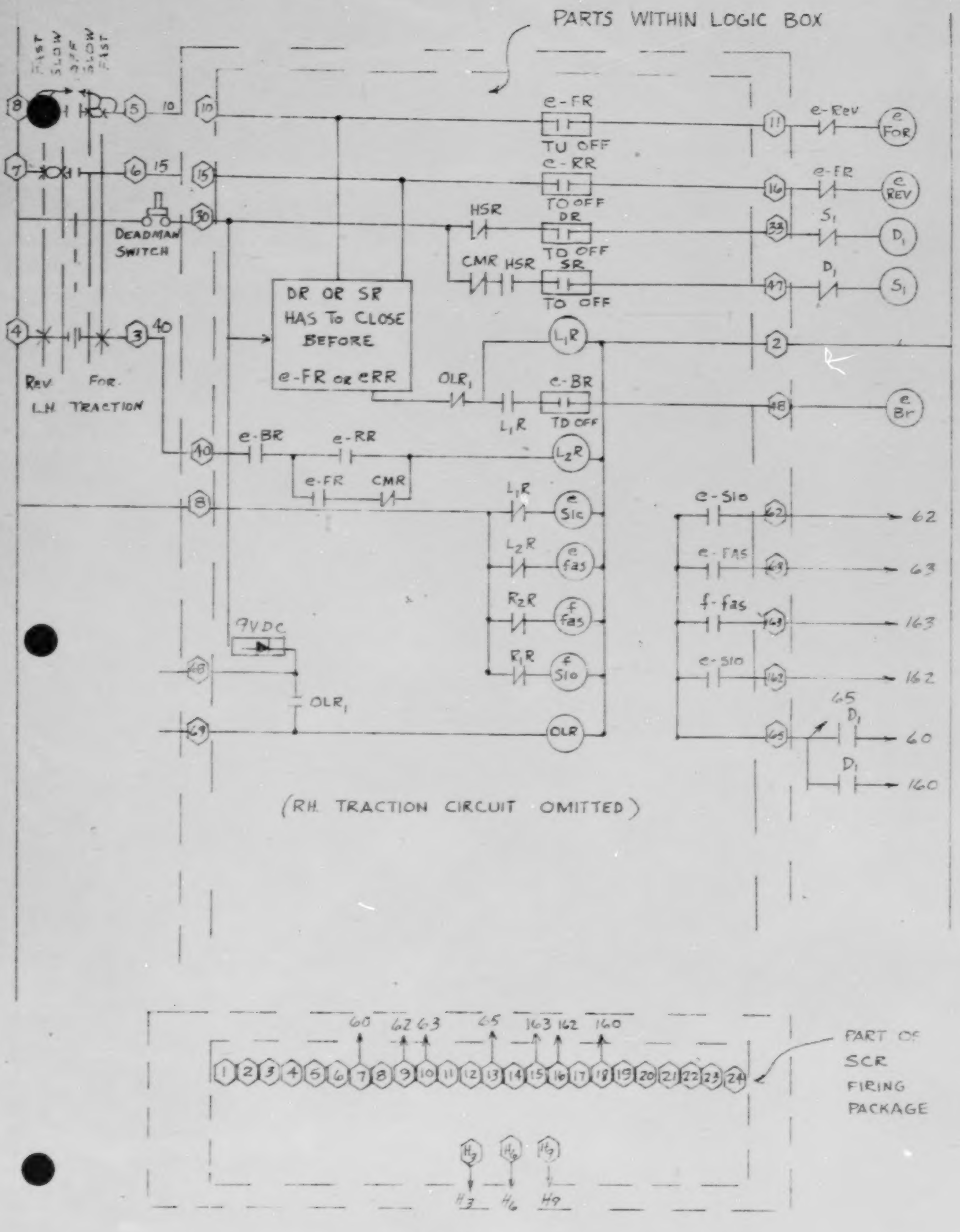

PARTS WITHIN LOGIC BOX
FAST
SLOW
OFF
SLOW
FAST
8
5
10
10
e-FR
TU OFF
11
e-Rev
e For
7
6
15
15
e-RR
TO OFF
16
e-FR
e REV
DEADMAN SWITCH
30
HSR
DR
TO OFF
33
S1
D1
CMR
HSR
SR
TO OFF
47
D1
S1
DR OR SR HAS TO CLOSE BEFORE e-FR OR eRR
4
3
40
L1R
2
REV
FOR.
L.H. TRACTION
OLR1
e-BR
TD OFF
L1R
48
e Br
40
e-BR
e-RR
L2R
e-FR
CMR
8
L1R
e S1o
L2R
e fas
R2R
f fas
R1R
f S1o
9VDC
68
OLR1
69
OLR
e-S1o
62
62
e-FAS
63
63
f-fas
163
163
e-S1o
162
162
65
65
D1
60
D1
160
(RH. TRACTION CIRCUIT OMITTED)
60
62
63
65
163
162
160
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
PART OF SCR FIRING PACKAGE
H3
H6
H9
H3
H6
H9

DIAGRAM 3

10-24

STUDENT COMPETENCY SHEET #1

UNIT: 11 CIRCUIT CONNECTIONS: AC/DC SOLID STATE

COMPETENCY STATEMENT: INTERCONNECTS SOLID STATE COMPONENTS AND DEVICES ON AN AC/DC SOLID STATE PANEL

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL INTERCONNECT SOLID STATE COMPONENTS AND DEVICES ON AN AC/DC SOLID STATE PANEL AND TAKE METER READINGS.

CONDITIONS: YOU HAVE 30 MINUTES TO DO ALL WORK. YOU HAVE THESE ITEMS TO WORK WITH: AN AC/DC SOLID STATE PANEL, REPLACEMENT SOLID STATE COMPONENTS AND DEVICES, HAND TOOLS, VOM, SCHEMATIC DIAGRAMS, AND WIRING DIAGRAMS.

STANDARD: THIS IS HOW WELL YOU MUST DO:

1. AFTER YOU HAVE COMPLETED THE INTERCONNECTIONS, THE METER READINGS MUST BE LIKE THOSE ON THE DIAGRAMS.
2. AFTER YOU HAVE COMPLETED THE INTERCONNECTIONS, THE PANEL MUST WORK LIKE IT SHOULD.
3. YOU MUST WORK SAFELY AND NOT DAMAGE TOOLS OR PARTS.
4. YOU MUST GET DONE IN 30 MINUTES.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "KNOW THE PANEL," FROM THE INSTRUCTOR. DO ALL THE THINGS LISTED ON THE HANDOUT.
2. GET STUDENT HANDOUT #2, "KNOW THE INTERCONNECTIONS," FROM THE INSTRUCTOR. DO ALL THE THINGS LISTED ON THE HANDOUT.
3. GET STUDENT HANDOUT #3, "AC/DC SOLID STATE: MAIN INTERCONNECTIONS," FROM THE INSTRUCTOR. DO ALL THE THINGS LISTED ON THE HANDOUT.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

UNIT: 11 CIRCUIT CONNECTIONS: AC/DC SOLID STATE

KNOW THE PANEL

DO THESE THINGS:

1. GET THE SCHEMATIC AND WIRING DIAGRAMS FOR THE AC/DC SOLID STATE PANEL. GO TO THE PANEL WITH THE DIAGRAMS. FIND THE FIRING PACKAGE ON THE PANEL AND ON THE DIAGRAMS. ANSWER THESE QUESTIONS:
   - A. HOW MANY CONNECTIONS ARE THERE FOR THE FIRING PACKAGE?
   - B. WHAT TYPES OF MARKINGS ARE USED TO IDENTIFY THE LEADS FOR THE FIRING PACKAGE?
   - C. WHERE ARE THE SCR GATE LEADS FOR THE LEFT MOTOR?
   - D. WHERE ARE THE SCR GATE LEADS FOR THE RIGHT MOTOR?
   - E. WHAT OTHER COMPONENTS ARE CONNECTED TO THE FIRING PACKAGE?

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

2. FIND THE LOGIC BOX ON THE PANEL AND ON THE DIAGRAMS. ANSWER THESE QUESTIONS:
   - A. HOW MANY CONNECTIONS ARE THERE ON THE LOGIC BOX?
   - B. DESCRIBE HOW THE LEADS FOR THE LOGIC BOX ARE IDENTIFIED.
   - C. DESCRIBE HOW TO CHANGE THE LOGIC BOX. WHAT CAN BE DONE WITH THE TERMINALS TO MAKE CHANGING EASIER?

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

3. FIND THE SCR BRIDGE ON THE PANEL AND ON THE DIAGRAMS. ANSWER THESE QUESTIONS:

   A. WHAT WOULD YOU USE TO TELL IF AN SCR WAS "BAD"?

   B. WHAT OTHER COMPONENTS ARE CONNECTED TO THE SCR BRIDGE?

   C. WHAT WOULD BE THE HARDEST THING TO DO IF YOU HAD TO CHANGE AN SCR BRIDGE?

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

STUDENT HANDOUT #2

UNIT: 11 CIRCUIT CONNECTIONS: AC/DC SOLID STATE

DO THESE THINGS:

1. A PERSON GIVES YOU A LOGIC BOX. ALL LEADS ARE CONNECTED TO THE LOGIC BOX. THE OTHER END OF EACH LEAD IS DANGLING IN THE AIR. YOUR JOB IS TO TELL WHAT EACH LEAD WOULD BE INTERCONNECTED TO. USE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, AND THE PANEL.

   A. TERMINAL #2 IS INTERCONNECTED TO
   B. TERMINAL #8 IS INTERCONNECTED TO
   C. TERMINAL #30 IS INTERCONNECTED TO
   D. TERMINAL #65 IS INTERCONNECTED TO
   E. TERMINAL #70 IS INTERCONNECTED TO
   F. TERMINAL #80 IS INTERCONNECTED TO
   G. TERMINAL #110 IS INTERCONNECTED TO
   H. TERMINAL #140 IS INTERCONNECTED TO
   I. TERMINAL #15 IS INTERCONNECTED TO
   J. TERMINAL #10 IS INTERCONNECTED TO

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

2. A PERSON GIVES YOU A FIRING PACKAGE. ALL LEADS ARE CONNECTED TO THE FIRING PACKAGE. THE OTHER END OF EACH LEAD IS DANGLING IN THE AIR. YOUR JOB IS TO TELL WHAT EACH LEAD WOULD BE INTERCONNECTED TO. USE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, AND THE PANEL.

A. TERMINAL #H-3 IS INTERCONNECTED TO

B. TERMINAL #H-6 IS INTERCONNECTED TO

C. TERMINAL #H-9 IS INTERCONNECTED TO

D. TERMINAL #7 IS INTERCONNECTED TO

E. TERMINAL #9 IS INTERCONNECTED TO

F. TERMINAL #10 IS INTERCONNECTED TO

G. TERMINAL #12 IS INTERCONNECTED TO

H. TERMINAL #16 IS INTERCONNECTED TO

I. TERMINAL #18 IS INTERCONNECTED TO

J. TERMINAL #1 IS INTERCONNECTED TO

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

3. USE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, AND THE PANEL TO ANSWER THESE QUESTIONS ABOUT THE SCR BRIDGE.

   A. PHASE B-1 OF THE SCR BRIDGE CIRCUIT BREAKER CONNECTS TO ONE OF THE SCRs. WHERE IS THE GATE LEAD FOR THIS SCR CONNECTED?

   B. PHASE B-2 OF THE SCR BRIDGE CIRCUIT BREAKER CONNECTS TO ONE OF THE SCRs. WHERE IS THE GATE LEAD FOR THIS SCR CONNECTED?

   C. THERE ARE TWO LEADS GOING TO EACH SCR. ONE IS RED AND THE OTHER IS WHITE. WHICH ONE IS THE GATE LEAD?

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

STUDENT HANDOUT #3

UNIT: 11 CIRCUIT CONNECTIONS: AC/DC SOLID STATE

AC/DC-SOLID STATE: MAIN INTERCONNECTIONS

DO THESE THINGS:

1. TAKE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, HAND TOOLS, AND VOM AND GO TO THE AC/DC-SOLID STATE PANEL. PUT THE PANEL THROUGH ALL OPERATING POSITIONS. TAKE ALL METER READINGS AT THE LOGIC BOX. REMOVE AND REPLACE THE LOGIC BOX. HAVE YOUR INSTRUCTOR CHECK YOUR WORK. ENERGIZE THE PANEL. TAKE METER READINGS AND WRITE THEM DOWN. SHOW THEM TO YOUR INSTRUCTOR SO HE CAN TELL IF THE PANEL WORKS THE WAY IT SHOULD.

2. TAKE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, HAND TOOLS, AND VOM AND GO TO THE AC/DC-SOLID STATE PANEL. PUT THE PANEL THROUGH ALL OPERATING POSITIONS. TAKE ALL METER READINGS FOR THE FIRING PACKAGE. REMOVE AND REPLACE THE FIRING PACKAGE. HAVE YOUR INSTRUCTOR CHECK YOUR WORK. ENERGIZE THE PANEL. TAKE METER READINGS AND WRITE THEM DOWN. SHOW THEM TO YOUR INSTRUCTOR SO HE CAN TELL IF THE PANEL WORKS THE WAY IT SHOULD.

3. TAKE YOUR SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, HAND TOOLS, AND VOM AND GO TO THE AC/DC-SOLID STATE PANEL. PUT THE PANEL THROUGH ALL OPERATING POSITIONS. TAKE ALL METER

READINGS FOR THE SCR BRIDGE. REMOVE AND REPLACE THE SCR BRIDGE. HAVE YOUR INSTRUCTOR CHECK YOUR WORK. ENERGIZE THE PANEL. TAKE METER READINGS AND WRITE THEM DOWN. SHOW THEM TO YOUR INSTRUCTOR SO HE CAN TELL IF THE PANEL WORKS THE WAY IT SHOULD.

STUDENT COMPETENCY SHEET #1

UNIT: 12 CONTROL POSITIONS AND TERMINAL VOLTAGES

COMPETENCY STATEMENT: IDENTIFIES ALL OPERATING CONTROL POSITIONS BASED ON METER READINGS FOR AN AC/DC/SOLID-STATE PANEL

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT CONTROL POSITIONS AND METER READINGS FOR AN AC/DC/SOLID-STATE PANEL.

CONDITIONS: YOU HAVE 30 MINUTES TO ANSWER THE QUESTIONS. YOU MAY USE REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. IF YOUR INSTRUCTOR TELLS YOU, REVIEW STUDENT HANDOUT #1, "TRACING PULSE, AC/DC - SOLID-STATE PANEL."
2. GET STUDENT HANDOUT #1,"CONTROL POSITIONS AND TERMINAL VOLTAGES," FROM THE INSTRUCTOR. LOOK AT DIAGRAMS #1-#4. THEY ARE THE SAME DIAGRAMS YOU WORKED WITH WHEN YOU TRACED THE PULSE FOR THE AC/DC - SOLID STATE PANEL.
3. READ STUDENT HANDOUT #1,"CONTROL POSITIONS AND TERMINAL VOLTAGES."
4. TAKE STUDENT HANDOUT #1,"CONTROL POSITIONS AND TERMINAL VOLTAGES," AND GO TO THE AC/DC - SOLID STATE PANEL. FIND EACH CONTROL AND TERMINAL DESCRIBED IN THE HANDOUT.
5. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

CONTROL POSITIONS AND TERMINAL VOLTAGES

Unit: 12 Control Positions and Terminal Voltages

A great amount of time is spent looking for problems in electrical systems. This need not be the case. Most of the time the problem is a simple one. If we use a logical sequence for finding a problem the battle is almost won. An important step in this sequence is knowing what switches must be on or off to get certain readings or checks within any system. Earlier you learned the operation of various circuits and traced out the current flow. A review of that material now might be of great help to you.

Look at Diagrams #1-#4 while studying this handout. (If you have WD 3536-36 from Joy Manufacturing, do not use Diagrams #1-#4.)

I. Circuit Breakers:

There are five circuit breakers in this system. Find them on the diagrams.

A. 1CB - This connects the left and right cutter motors to the power source, L1, L2, and L3. At first it may look like this circuit breaker need not be closed to operate the other parts of the machine. On the machine, however, there is an "R" relay coil. This coil works with the methane monitor. It makes sure that this circuit will not operate when there is a dangerous amount of methane. An "R" coil usually makes connection to the entire operating circuit. Under normal conditions 1CB would have to be closed.

B. 2CB - THIS BREAKER CONNECTS THE REST OF THE POWER CIRCUIT TO THE POWER SOURCE. NOTICE THAT L1, L2, AND L3 NOW BECOME, L11, L12, AND L13. THIS SHOWS THAT THEY HAVE COME THROUGH A POWER INTERRUPTING DEVICE.

C. 3CB (BRIDGE BREAKER) - THIS CONNECTS THE TRAM CIRCUIT TO THE POWER TRANSFORMER SECONDARY. NOTICE THAT 1CB AND 2CB ARE CONNECTED TO "LINE VOLTAGE." ALL COMPONENTS THAT CONNECT TO THEM ARE ALSO AT LINE VOLTAGE. THE TRANSFORMER SECONDARY WILL BE AT 120 VOLTS AC IN DELTA AND 208 VOLTS AC IN WYE.

D. 5CB AND 6CB - THESE CONNECT THE OPERATING CIRCUIT AND LIGHT CIRCUIT. THEY ARE CONNECTED TO THE CONTROL TRANSFORMER SECONDARY. THEY ARE AT 120 VOLTS AC.

II. SWITCHES:

A. CONTROL SWITCH - THIS SWITCH MUST BE CLOSED IN ORDER FOR THE OPERATING CIRCUIT TO FUNCTION. IT IS AT 120 VOLTS AC.

B. PUMP AND TRACTION SWITCH - THIS SWITCH MUST BE IN THE RUN OR FAST POSITION TO OPERATE ANY CIRCUIT EXCEPT LIGHTING. IT IS AT 120 VOLTS AC.

C. TRAM SWITCH - THIS SWITCH MUST BE OFF TO START THE MACHINE. IT MUST BE IN SLOW OR FAST POSITION BEFORE THE SCR BRIDGE WILL FIRE. THIS IS A SEQUENCE TYPE SWITCH. IT WILL NOT SEND A 120 VOLT AC SIGNAL TO THE LOGIC BOX UNLESS THE FOOTSWITCH OR DEADMAN IS CLOSED FIRST. IN THE SLOW

POSITION, WITH THF FOOTSWITCH CLOSED, THE TRAM SWITCH PICKS UP L1R RELAY. IN THE FAST POSITION IT PICKS UP L2R RELAY.

D. FOOTSWITCH (DEADMAN) - THIS SWITCH MUST BE CLOSED FIRST BEFORE THE LOGIC BOX WILL ACCEPT A SIGNAL. THIS SWITCH WILL CLOSE EITHER D1 CONTACTOR OR S1 CONTACTOR. THIS DEPENDS ON THE POSITION OF THE PUMP AND TRACTION SWITCH. IF THE PUMP AND TRACTION SWITCH IS IN RUN, D1 WILL CLOSE. IF THE PUMP AND TRACTION SWITCH IS IN FAST, S1 WILL CLOSE.

III. TERMINAL VOLTAGES:

A. 1. ALL INPUT SIGNALS TO THE LOGIC BOX ARE 120 VOLTS AC.

2. TERMINAL #8 - MAIN SUPPLY VOLTAGE, 120 VOLTS AC.

3. TERMINALS #10, 15, 30, AND 40 ARE FOR LEFT HAND TRACTION MOTOR CONTROL.

4. TERMINALS #110, 115, AND 140 ARE FOR RIGHT HAND TRACTION MOTOR CONTROL.

5. ALL VOLTAGE READINGS WILL BE FROM THE TERMINALS MENTIONED, TO TERMINAL #2. THIS IS COMMON TO ALL TERMINALS.

B. OUTPUT TERMINALS

1. #11, 16, 33, AND 47, (48 WHEN SO EQUIPPED) ARE 120 VOLTS AC.

2. IF YOU CAN READ A VOLTAGE BETWEEN THESE POINTS AND TERMINAL #2 DEPENDS ON WHETHER THERE IS AN INPUT SIGNAL TO ITS CORRESPONDING TERMINAL ON THE INPUT SIDE. THIS IN TURN DEPENDS ON THE SWITCH POSITIONS.

3. With the pump motor running, the footswitch closed and left-hand tram switch in slow forward, you would read 120 volts AC at the following terminals: #8 to #2; #30 to #2; #33 to #2; #10 to #2; #11 to #2.
4. On the other hand, there would be no voltage from point #47 to #2 because the HSR contact is open and D1 interlock is also open.
5. Neither would there be a voltage reading at points #15 to #2 because this is the reverse position and we are in slow forward position. Study the diagram carefully and be sure that you understand these points.

c. Logic Box Voltage

1. Across #68 to #2 measures 8 to 10 volts DC when the pump motor is running and with 120 volts AC to point #8. The footswitch must be closed.
2. If no voltage appears at this point, release the footswitch and reclose it before you decide the logic box is no good. This acts as a reset because there is a latching type relay on the normally open contacts at OLR1. If an overload occurs, OLR1 closes and is latched. Resetting the footswitch will release it.

D. FIRING PACKAGE VOLTAGE:

1. ACROSS #12 TO #13 MEASURES 24 VOLTS DC WHEN THE "D" LINE STARTER IS CLOSED.
2. REMEMBER THE TRANSFORMER PRIMARY; H3, H6, AND H9 (440 VOLTS AC) AND H1, H4, AND H7 (550 VOLTS AC). THIS IS A THREE PHASE CONNECTION AND VOLTAGE READINGS MUST BE TAKEN BETWEEN ALL PHASES TO BE SURE THERE IS PROPER VOLTAGE FOR THE OPERATION OF THE FIRING PACKAGE. VOLTAGE READINGS MUST NOT VARY MORE THAN 5 PERCENT BETWEEN EACH PHASE. LINE VOLTAGE MUST NOT VARY MORE THAN 10 PERCENT IN EITHER DIRECTION.
3. THIS MEANS THAT 440 SOURCE VOLTAGE MAY BE APPROXIMATELY 480 VOLTS OR AS LOW AS 396 VOLTS AND BE ACCEPTABLE.
4. IT ALSO MEANS THAT 440 PHASE TO PHASE MAY BE NO MORE THAN 462 VOLTS AND NO LESS THAN 418 VOLTS AC. THESE FIGURES REPRESENT SAMPLES ONLY. THEY SHOULD NOT BE USED AS SPECIFICATIONS. TO BE CERTAIN OF YOUR MEASUREMENTS IN THE FIELD, MULTIPLY YOUR ACTUAL VOLTAGE PHASE TO PHASE BY 0.5 TO DETERMINE THE PHASE DIFFERENCE.
5. EACH TERMINAL ON THE SCR FIRING PACKAGE, #1 THROUGH #24, HAS ITS OWN PURPOSE AND VOLTAGE READING.
    - (A) TERMINALS #1 THROUGH #6 PROVIDE THE PULSE TO THE SCR BRIDGE OF THE LEFT HAND TRACTION CIRCUIT.
    - (B) THE NUMBERS FOR THE RIGHT HAND TRACTION CIRCUIT ARE #19 THROUGH #24.

(c) Normal readings for low speed at these terminals will be about 0.5 volts DC, and high speed, 1.0 volts DC. Under no circumstances should these voltages exceed 2 volts DC.

(d) These voltages may vary depending on the SCR characteristics. The important thing here is that we have an increase in voltage at these points when going from low to high tram and that the voltage never exceeds 2 volts DC.

(e) Terminals #60 and #160 are in series with A-D1 contact. These are used when the machine is in low tram and signal the firing package that low tram has been selected by the operator. In low tram, voltage across these interlocks will be zero and 1.5 volts DC in high slow or high fast.

(f) Terminals #62 and #65 are for the Pump Switch. With the Pump Switch in run or fast position,-Footswitch closed, Tram lever in first position, voltage between these points will be 14 volts DC and #63 to #65 will read zero. When the Tram lever is moved to the second or fast position, L2R picks up and the voltage between #63 and #65 should be 18 volts DC. It should be 17 volts DC between #62 and #65.

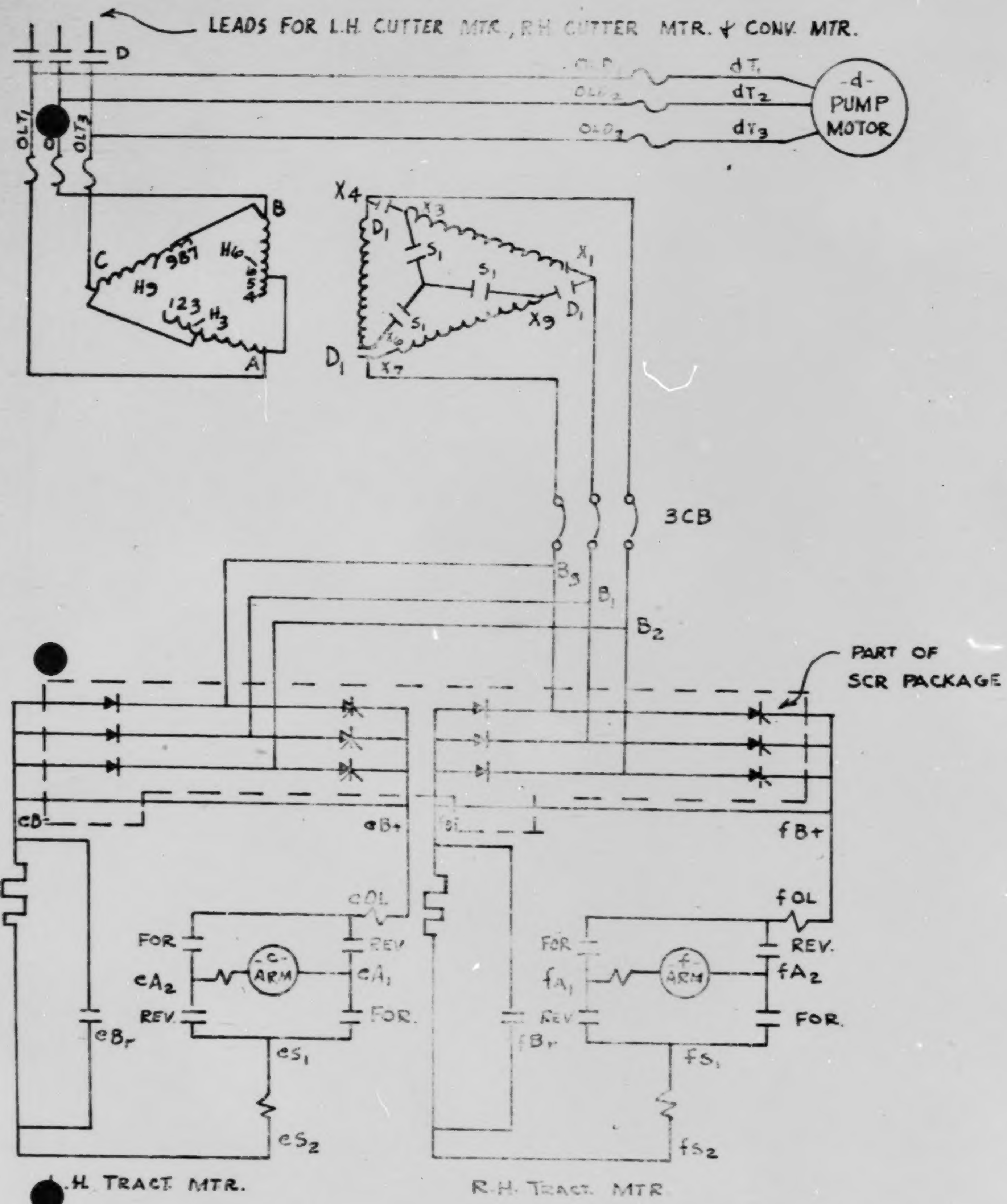

LEADS FOR L.H. CUTTER MTR., R.H. CUTTER MTR. & CONV. MTR.
D
OLT1
OLT2
OLT3
OLD1
OLD2
OLD3
dT1
dT2
dT3
-d-
PUMP
MOTOR
B
C
987
H6
6
5
4
H9
123
H3
A
X4
X3
D1
S1
S1
X1
S1
X6
X9
D1
D1
X7
3CB
B3
B1
B2
PART OF
SCR PACKAGE
eB-
eB+
fB-
fB+
eOL
fOL
FOR
REV
eA2
-e-
ARM
eA1
REV.
FOR.
eBr
eS1
eS2
FOR
fA1
-f-
ARM
REV.
fA2
REV
FOR.
fBr
fS1
fS2
L.H. TRACT. MTR.
R.H. TRACT. MTR

DIAGRAM 1

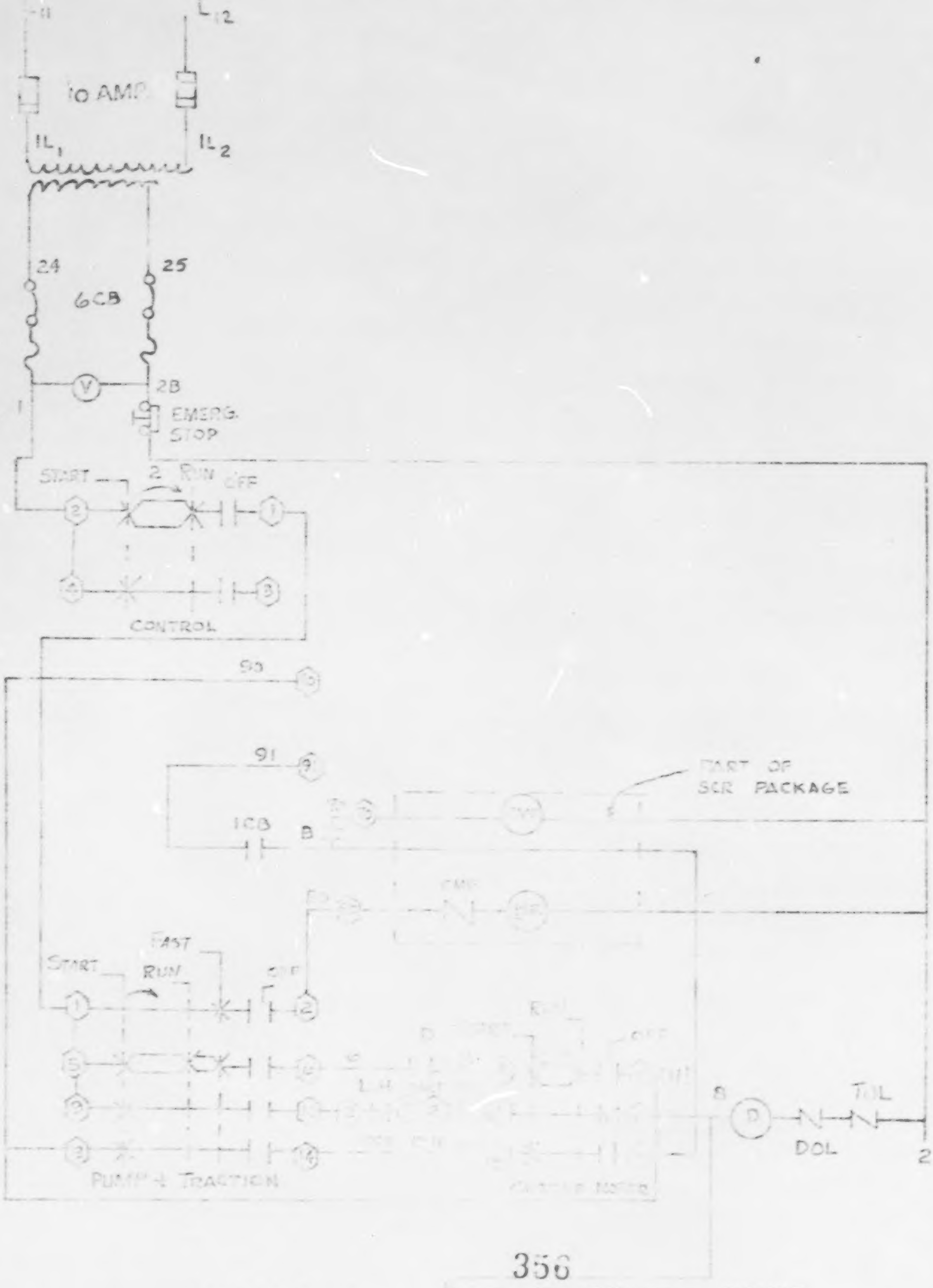

L11
L12
10 AMP.
1L1
1L2
24
25
6CB
V
2B
1
EMERG.
STOP
START
2
RUN
OFF
CONTROL
90
91
PART OF
SCR PACKAGE
1CB
B
CMP
START
FAST
RUN
OFF
D
8
D
DOL
TOL
2
PUMP + TRACTION
B ← TO CONVEYOR CIRCUIT

DIAGRAM 2

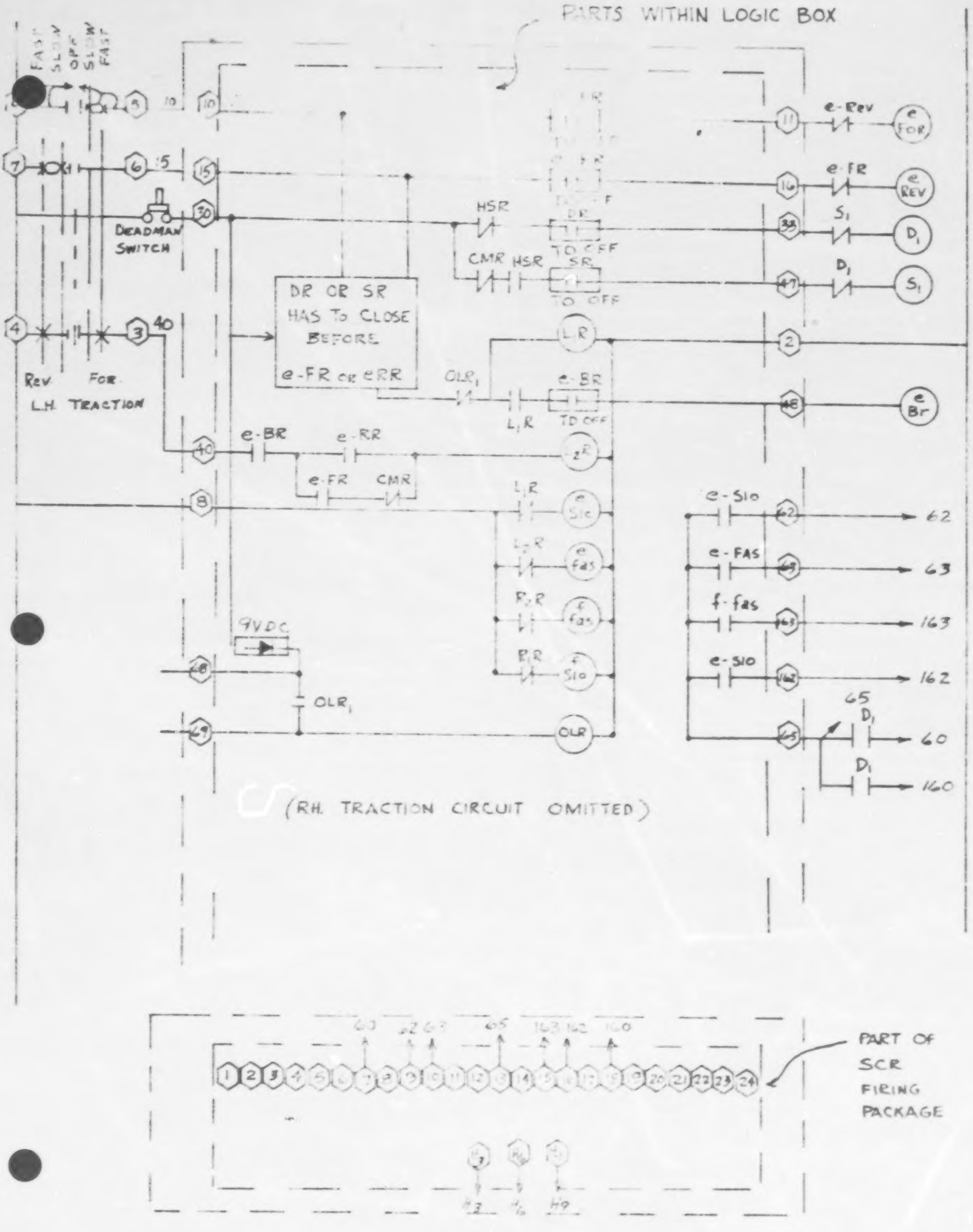

PARTS WITHIN LOGIC BOX
FAST
SLOW
OFF
SLOW
FAST
7
6
15
5
10
10
15
30
DEADMAN SWITCH
4
3
40
REV
FOR
L.H. TRACTION
DR OR SR HAS TO CLOSE BEFORE e-FR OR eRR
HSR
CMR
HSR
DR
TO OFF
SR
TO OFF
11
e-Rev
e FOR
16
e-FR
e REV
33
S1
D1
47
D1
S1
L1R
2
OLR1
e-BR
TD OFF
L1R
48
e Br
40
e-BR
e-RR
e-FR
CMR
L2R
8
L1R
e Slo
L2R
e fas
R2R
f fas
R1R
f Slo
9VDC
68
69
OLR1
OLR
e-Slo
62
62
e-FAS
63
63
f-fas
163
163
e-Slo
162
162
65
65
D1
60
D1
160
(RH. TRACTION CIRCUIT OMITTED)
60
62
63
65
163
162
160
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
PART OF SCR FIRING PACKAGE
H3
H6
H9
H3
H6
H9

DIAGRAM 5

12-10

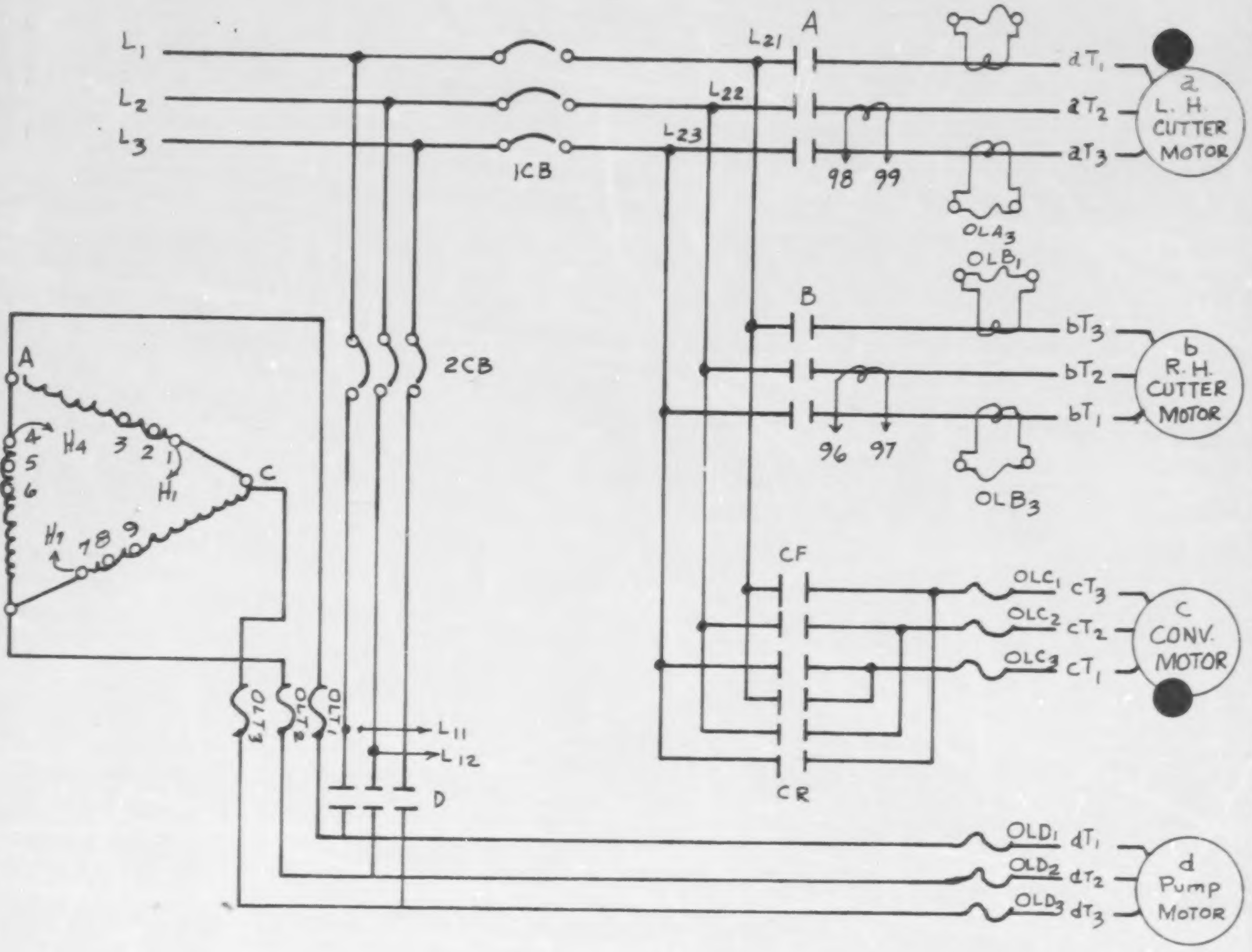

L1
L2
L3
1CB
2CB
L21
L22
L23
A
B
CF
CR
D
98
99
96
97
OLA3
OLB1
OLB3
OLC1
OLC2
OLC3
OLD1
OLD2
OLD3
OLT1
OLT2
OLT3
L11
L12
aT1
aT2
aT3
bT1
bT2
bT3
cT1
cT2
cT3
dT1
dT2
dT3
a
L. H.
CUTTER
MOTOR
b
R. H.
CUTTER
MOTOR
c
CONV.
MOTOR
d
Pump
Motor
A
B
C
H4
H1
H7
1
2
3
4
5
6
7
8
9

DIAGRAM 4

STUDENT EXAMINATION #1

UNIT: 12 CONTROL POSITIONS AND TERMINAL VOLTAGES

USES DIAGRAMS #1-#4 WHEN ANSWERING THESE QUESTIONS. YOU MAY ALSO USE STUDENT HANDOUT #1, CONTROL POSITIONS AND TERMINAL VOLTAGES.

1. (A) WHICH CONTROL WOULD HAVE TO BE IN A CLOSED POSITION IN ORDER TO MEASURE VOLTAGE AT THE CUTTER MOTORS CONTACTORS?

   ____

   (B) WHAT VOLTAGE SHOULD BE MEASURED THERE? ____________________

   (C) LOCATE AND CIRCLE THE CONTROL ON THE DIAGRAM AND MARK IT #1.

2. WITH 2CB CLOSED AND CONTROL SWITCH AND PUMP TRACTION SWITCH IN PROPER POSITION LOCATE, CIRCLE, AND MARK AS #2 THE CONTROL THAT WOULD ACCOMPLISH ALL OF THE FOLLOWING WHEN IN THE CLOSED POSITION.

   (A) CLOSES D1 CONTACTOR

   (B) OPENS D1 INTERLOCK

   (C) CLOSES TWO D1 CONTACTS

   (D) CAUSES POWER TRANSFORMER SECONDARY TO GO INTO DELTA CONFIGURATION.

3. LOCATE, CIRCLE, AND MARK AS #3 ON THE DIAGRAM, ALL CONTROLS THAT WOULD HAVE TO BE CLOSED BEFORE ANY OF THE ACTION IN QUESTION #2 WOULD TAKE PLACE.

4. WE WISH TO MEASURE THE LOWEST GATE PULSE AT THE LEFT HAND TRACTION MOTOR. LIST THE NAMES OF ALL CONTROLS THAT MUST BE CLOSED TO ACCOMPLISH THIS TASK AND THEIR POSITIONS?

   (1)

   (2)

(3)

(4)

(5)

(6)

(7)

5. CIRCLE AND MARK AS #5, ONE CIRCUIT BREAKER THAT NEED NOT BE CLOSED TO ACCOMPLISH THE TASK IN QUESTION #4.

6. WRITE THE NUMBERS OF THE TERMINALS AT WHICH YOU WOULD TAKE THE VOLTMETER READINGS FOR ANY GATE PULSE.

7. WITH THE PUMP AND TRACTION MOTORS RUNNING, WRITE THE NAMES AND POSITIONS OF ALL CONTROLS REQUIRED TO OBTAIN THE MAXIMUM DC VOLTAGE POSSIBLE AT THE SCR BRIDGE.

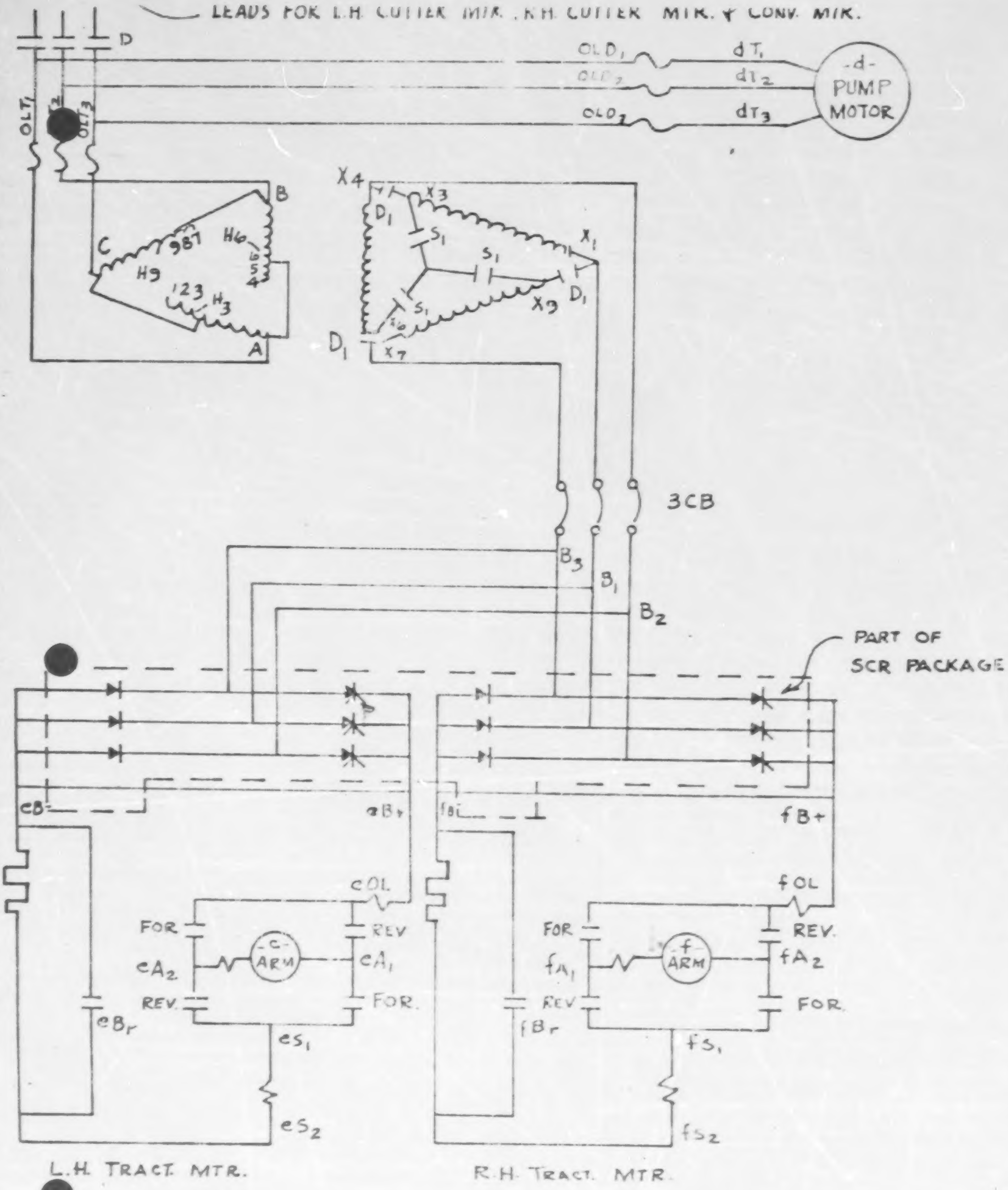
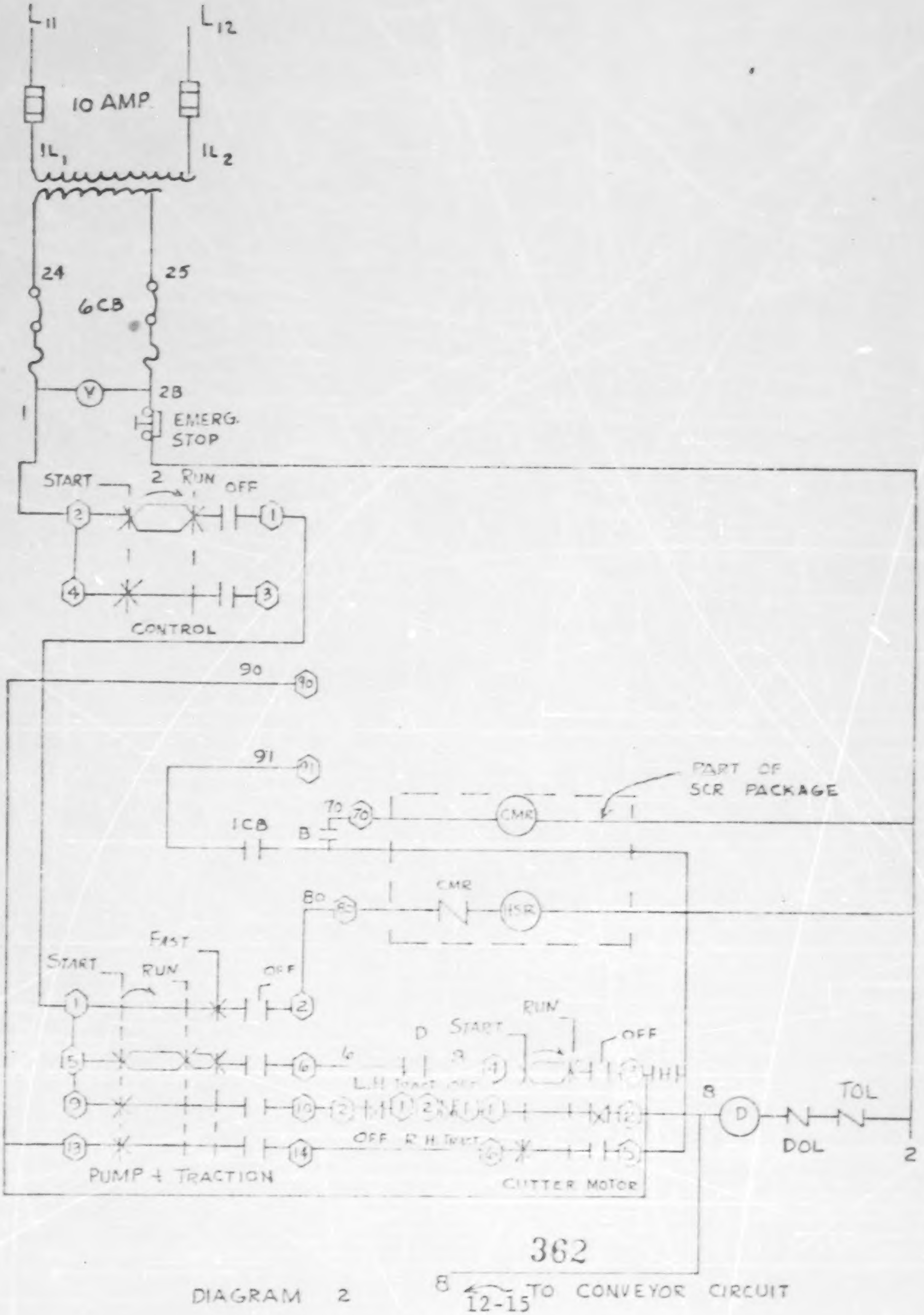

LEADS FOR L.H. CUTTER MTR., R.H. CUTTER MTR. & CONV. MTR.
D
OLT1
OLT2
OLT3
OLD1
OLD2
OLD3
dT1
dT2
dT3
-d-
PUMP MOTOR
B
C
A
987
H6
6
5
4
H9
123
H3
X4
X3
D1
S1
S1
X1
S1
D1
X9
X6
D1
X7
3CB
B3
B1
B2
PART OF SCR PACKAGE
eB-
eB+
fB-
fB+
eOL
fOL
FOR
REV
-e-
ARM
eA2
eA1
REV.
FOR.
eBr
eS1
eS2
FOR
REV.
-f-
ARM
fA1
fA2
REV
FOR.
fBr
fS1
fS2
L.H. TRACT. MTR.
R.H. TRACT. MTR.

DIAGRAM 1



L11
L12
10 AMP.
1L1
1L2
24
25
6CB
V
1
2B
EMERG. STOP
START
2
RUN
OFF
2
1
4
3
CONTROL
90
90
91
91
PART OF SCR PACKAGE
70
70
CMR
1CB
B
80
CMR
HSR
FAST
START
RUN
OFF
1
2
5
6
D
START
RUN
OFF
9
10
13
14
L.H. TRACT. OFF
OFF R.H. TRACT.
PUMP + TRACTION
CUTTER MOTOR
8
D
TOL
DOL
2
8
12-15
TO CONVEYOR CIRCUIT

DIAGRAM 2

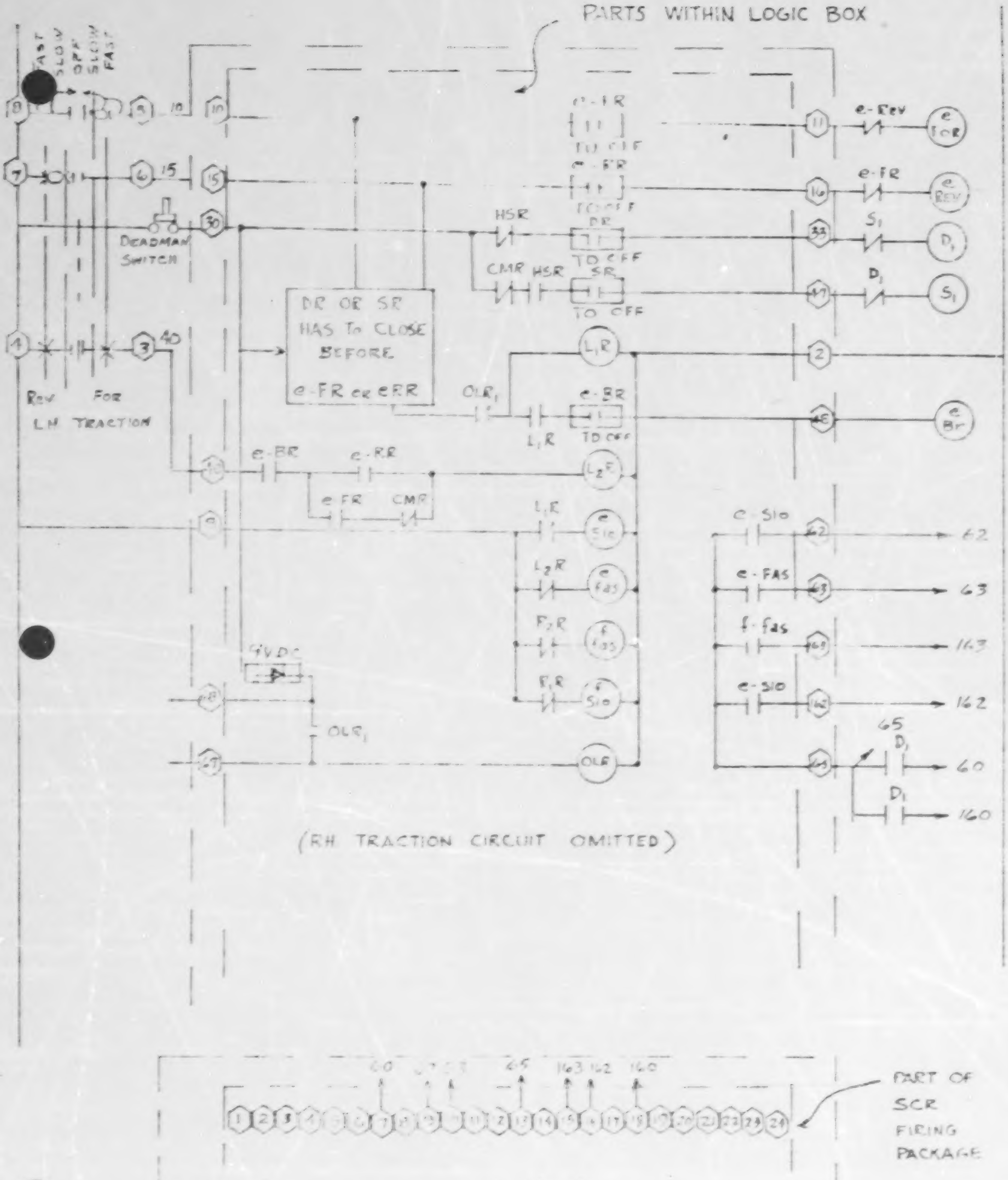

PARTS WITHIN LOGIC BOX
FAST
SLOW
OFF
SLOW
FAST
DEADMAN SWITCH
REV
FOR
LH TRACTION
e-FR
TO OFF
e-Rev
e-FR
HSR
DR
TO OFF
S1
D1
CMR
HSR
SR
TO OFF
D1
S1
DR OR SR HAS TO CLOSE BEFORE e-FR OR ERR
L1R
OLR1
e-BR
L1R
TO OFF
e Br
e-BR
e-RR
L2R
e-FR
CMR
L1R
e Slo
L2R
e Fas
F2R
f fas
F1R
f Slo
9VDC
OLR1
OLR
e-Slo
e-FAS
f-fas
e-Slo
65
D1
D1
62
63
163
162
60
160
(RH TRACTION CIRCUIT OMITTED)
60
65
163
162
160
PART OF SCR FIRING PACKAGE
H7
H6
H9

DIAGRAM 5
12-16

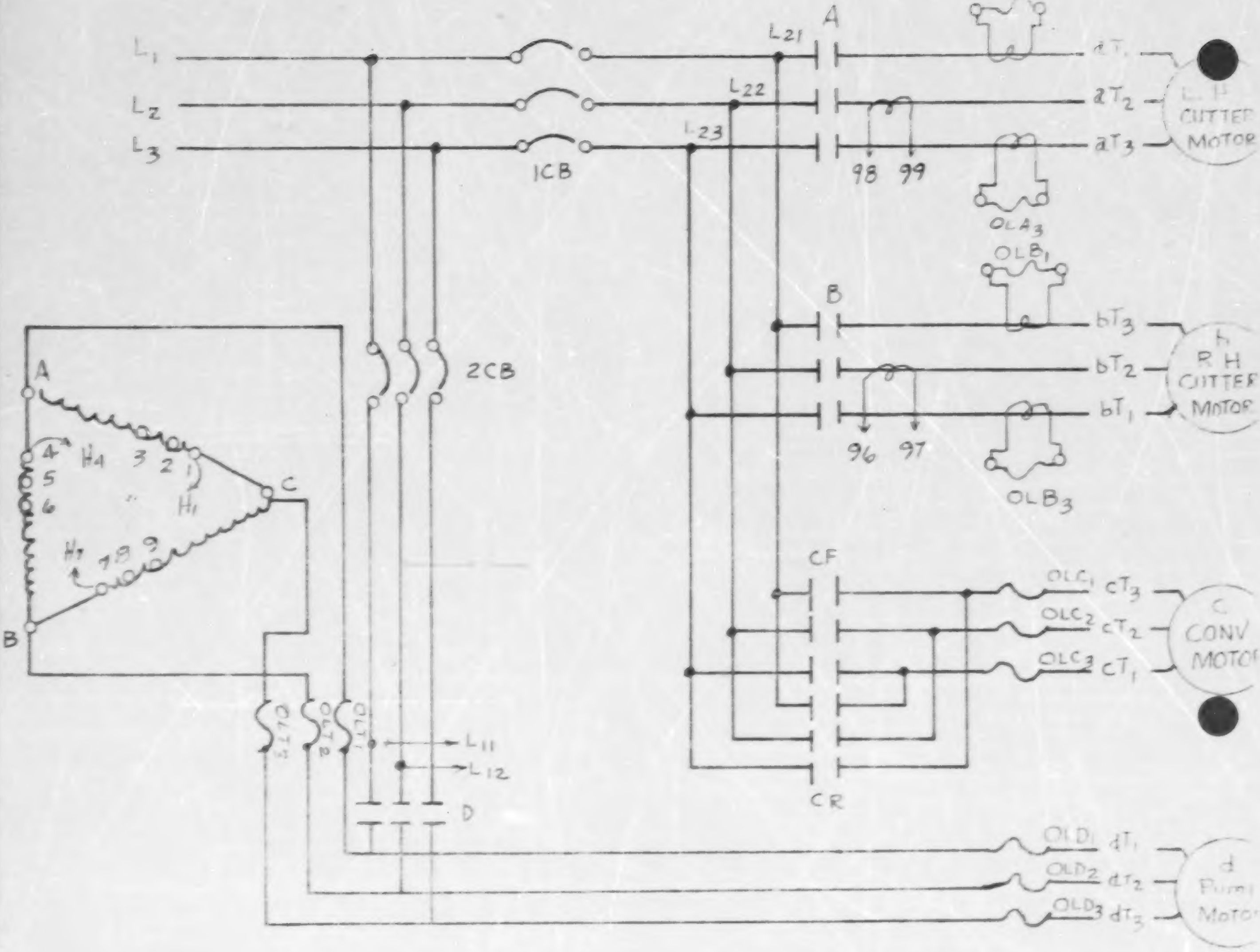

L1
L2
L3
1CB
L21
L22
L23
A
aT1
aT2
aT3
L H CUTTER MOTOR
98
99
OLA3
OLB1
B
bT3
bT2
bT1
R H CUTTER MOTOR
96
97
OLB3
2CB
A
4
5
6
H4
3
2
1
H1
C
H7
7
8
9
B
CF
OLC1
OLC2
OLC3
cT3
cT2
cT1
C CONV MOTOR
CR
OLT3
OLT2
OLT1
L11
L12
D
OLD1
OLD2
OLD3
dT1
dT2
dT3
d Pump Motor

DIAGRAM 4

STUDENT COMPETENCY SHEET #1

UNIT: 13 TROUBLESHOOTING: OPERATOR'S REMARKS

COMPETENCY STATEMENT: INTERPRETS OPERATOR'S REMARKS AND SPECIFIES PROBABLE CAUSE(S) FOR MALFUNCTIONS

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL ANSWER QUESTIONS ABOUT WHAT YOU CAN TELL ABOUT HOW A MACHINE WORKS FROM WHAT AN OPERATOR SAYS.

CONDITIONS: YOU HAVE 20 MINUTES TO DO THIS. YOU MAY USE SCHEMATIC AND WIRING DIAGRAMS AS REFERENCES.

STANDARD: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "WHAT IS SAID," FROM THE INSTRUCTOR. READ IT AND ANSWER ALL QUESTIONS.
2. GET STUDENT HANDOUT #2, "HOW MUCH DO YOU HEAR," FROM THE INSTRUCTOR. READ IT AND ANSWER ALL QUESTIONS.
3. GET STUDENT HANDOUT #3, "WHAT IS WRONG," FROM THE INSTRUCTOR. READ IT AND ANSWER ALL QUESTIONS.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

UNIT: 13 TROUBLESHOOTING: OPERATOR'S REMARKS

WHAT IS SAID

LET'S SAY YOU ARE AN AUTOMOBILE MECHANIC. A PERSON CALLS YOU ON THE TELEPHONE AND SAYS "MY CAR JUST WON'T DO ANYTHING WHEN I TURN THE KEY."

1. WRITE TWO THINGS YOU WOULD ASK THIS PERSON TO DO.

2. IF YOU WANTED TO KNOW WHAT THE CAR SOUNDED LIKE WHEN THE KEY WAS TURNED, WHAT WOULD YOU SAY TO THE PERSON?

3. DO YOU THINK IT WOULD BE IMPORTANT TO KNOW THE KIND OF CAR? WHY OR WHY NOT?

4. DO YOU THINK IT WOULD BE IMPORTANT TO KNOW HOW OLD THE CAR IS? WHY OR WHY NOT?

5. IF YOU HAD ONLY TWO THINGS YOU COULD ASK THE PERSON, WHAT WOULD THEY BE?

THE REASON WE DID THE LITTLE EXERCISE ABOVE IS TO TRY TO GET YOU TO THINK ABOUT LISTENING. IF YOU LISTEN TO WHAT IS SAID ABOUT HOW SOMETHING IS WORKING, THEN YOU MAY KNOW MORE WHAT TO DO TO FIX IT. LISTENING IS IMPORTANT BECAUSE OF THE AMOUNT OF STUFF SOMEONE SAYS.

LET'S LOOK AT THE CAR AGAIN. THE PERSON COULD HAVE SAID, "I HAVE PLENTY OF GAS. I JUST GOT A NEW BATTERY. THE BATTERY TURNS AND TURNS THE ENGINE. I SMELL A LOT OF GAS." OR THE PERSON COULD HAVE SAID, "I'M NOT SURE BUT I THINK MY CAR IS FLOODED." OR "I THINK MY AUTOMATIC CHOKE IS STUCK," OR "MY CAR DOESN'T SEEM TO FIRE." EACH OF THESE THINGS TELLS US SOMETHING. IN EACH CASE, WE WOULD TELL THE PERSON TO DO SOMETHING DIFFERENT. WE MAY ALSO ASK DIFFERENT QUESTIONS. IF WE WERE BY THE CAR, WE WOULD DO DIFFERENT THINGS.

LET'S TRY ONE MORE EXERCISE.

SUPPOSE SOMEONE SAYS, "MY CAR JUST GOES CLICK WHEN I TURN THE KEY."

1. WRITE TWO THINGS YOU WOULD ASK THIS PERSON TO DO.

2. WHAT TWO QUESTIONS COULD YOU ASK THIS PERSON? HAVE ANOTHER STUDENT WRITE ANSWERS TO YOUR QUESTIONS.

3. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG WITH THE CAR?

4. HOW SURE ARE YOU THAT YOU KNOW EXACTLY WHAT IS WRONG?

STUDENT HANDOUT #2

UNIT: 13 TROUBLESHOOTING OPERATOR'S REMARKS

HOW MUCH DO YOU HEAR

I. THESE PROBLEMS ARE ABOUT THE AC/DC SOLID STATE PANEL.

A. AN OPERATOR SAYS TO YOU, "IT DOES NOT RUN GOOD EITHER WAY."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO
2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK? WRITE AT LEAST TWO QUESTIONS.

B. AN OPERATOR SAYS TO YOU, "IT RUNS ONLY IN SLOW SPEED BOTH FORWARD AND BACKWARD."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO
2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK FIRST?

C. AN OPERATOR SAYS TO YOU, "IT RUNS AHEAD, BUT WILL ONLY GO FAST BACKWARDS."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO

2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK? WRITE AT LEAST TWO QUESTIONS.

D. AN OPERATOR SAYS TO YOU, "I CAN'T GET THE PUMP TO START AND I KNOW THE SWITCHES ARE OK."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS. CIRCLE THE CORRECT ANSWER. YES NO
2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK FIRST?

II. THESE PROBLEMS ARE ABOUT THE DC BATTERY POWERED PANEL.

A. AN OPERATOR SAYS TO YOU, "I CAN'T GET IT TO DO ANYTHING."

1. WHAT WOULD BE THE FIRST THING YOU WOULD TELL THE OPERATOR TO DO?

2. IF THE OPERATOR DID WHAT YOU ASKED AND IT DIDN'T WORK, WHAT IS ONE GOOD QUESTION YOU COULD ASK NOW?

B. AN OPERATOR SAYS TO YOU, "EACH TIME I GET A BIG LOAD IT DOESN'T WORK RIGHT."

1. WHAT WOULD YOU ASK THE OPERATOR TO FIND OUT WHAT A "BIG" LOAD IS?

2. WHAT WOULD YOU ASK THE OPERATOR TO FIND OUT WHAT "DOESN'T WORK RIGHT" MEANS?

C. AN OPERATOR SAYS TO YOU, "I CAN'T GET IT TO GO BACKWARD LIKE IT SHOULD."

1. WHAT WOULD YOU ASK TO FIND OUT WHAT THE OPERATOR MEANT BY "LIKE IT SHOULD?"

2. IF YOU ASKED THE QUESTION YOU WROTE ABOVE, WOULD YOU NEED TO ASK IF IT WORKED RIGHT GOING FORWARD?

III. THESE PROBLEMS ARE ABOUT THE AC PANEL.

A. AN OPERATOR SAYS TO YOU, "SOMETIMES THE MOTOR DOESN'T START."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO
2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK? WRITE AT LEAST TWO QUESTIONS.

B. AN OPERATOR SAYS TO YOU, "THE MOTOR WON'T RUN RIGHT ALL THE TIME."

1. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO
2. IF YOU NEED TO ASK MORE, WHAT DO YOU ASK FIRST?

STUDENT HANDOUT #3

UNIT: 13 TROUBLESHOOTING: OPERATOR'S REMARKS

WHAT IS WRONG

I. THESE PROBLEMS ARE ABOUT THE AC/DC SOLID STATE PANEL.

A. AN OPERATOR SAYS TO YOU, "IT RUNS ONLY FAST BOTH WAYS."

1. WRITE TWO QUESTIONS YOU COULD ASK THE OPERATOR. HAVE ANOTHER STUDENT ANSWER YOUR QUESTIONS.

2. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG?

B. AN OPERATOR SAYS TO YOU, "I KEEP THROWING THE BREAKERS."

1. WRITE THREE QUESTIONS YOU COULD ASK THE OPERATOR. HAVE ANOTHER STUDENT ANSWER YOUR QUESTIONS.

2. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG?

II. THESE PROBLEMS ARE ABOUT THE DC BATTERY POWERED PANEL.

A. AN OPERATOR SAYS TO YOU, "NOTHING HAPPENS WHEN I PUSH THE ACCELERATOR."

1. TELL THE OPERATOR TWO THINGS TO DO. HAVE ANOTHER STUDENT WRITE DOWN SOMETHING BESIDE EACH THING YOU WOULD TELL THE OPERATOR TO DO.

2. GOING BY WHAT THE STUDENT WROTE, WHAT IS WRONG?

B. AN OPERATOR SAYS TO YOU, "EVERY OTHER TIME I PUSH THE "STOP" BUTTON IT KEEPS ON RUNNING."

1. WRITE TWO QUESTIONS YOU COULD ASK THE OPERATOR. HAVE ANOTHER STUDENT ANSWER YOUR QUESTIONS.

2. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG?

III. THESE PROBLEMS ARE ABOUT THE AC PANEL.

A. AN OPERATOR SAYS TO YOU, "THE MOTOR RUNS TOO FAST SOME TIMES."

1. WRITE TWO QUESTIONS YOU COULD ASK THE OPERATOR. HAVE ANOTHER STUDENT ANSWER YOUR QUESTIONS.

2. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG?

B. AN OPERATOR SAYS TO YOU, "THE MOTOR JUST HUMS."

1. WRITE TWO QUESTIONS YOU COULD ASK THE OPERATOR. HAVE ANOTHER STUDENT ANSWER YOUR QUESTIONS.

2. GOING BY THE ANSWERS THE STUDENT GAVE YOU, WHAT IS WRONG?

STUDENT EXAMINATION #1

UNIT: 13 TROUBLESHOOTING: OPERATOR'S REMARKS

YOU CAN USE SCHEMATIC AND WIRING DIAGRAMS TO ANSWER THESE QUESTIONS.

1. YOU ARE TALKING TO AN OPERATOR WHO RUNS A MACHINE WITH AC, DC, AND SOLID STATE CONTROLS. THE OPERATOR TELLS YOU, "IT RUNS OK AHEAD, BUT WILL ONLY GO SLOW BACKWARDS."
    A. WHAT ARE THE TWO MOST IMPORTANT THINGS YOU CAN ASK?
    B. WHAT ARE TWO THINGS THAT COULD BE WRONG WITH THIS MACHINE?
2. YOU ARE TALKING TO AN OPERATOR WHO RUNS A MACHINE WITH AC, DC, AND SOLID STATE CONTROLS. THE OPERATOR SAYS TO YOU, "I CAN'T GET THE MAIN MOTORS TO RUN RIGHT."
    A. DO YOU NEED TO ASK SOME MORE QUESTIONS? CIRCLE THE CORRECT ANSWER. YES NO
    B. WHAT WOULD BE TWO THINGS YOU COULD HAVE THE OPERATOR DO SO YOU COULD BETTER TELL WHAT WAS WRONG?
    C. WHAT ARE TWO THINGS THAT COULD BE WRONG WITH THIS MACHINE?

3. You are talking to an operator who runs a machine with battery powered solid state controls. The operator tells you, "I can't get it to go fast backwards."
   - A. What would be one thing you could have the operator do so you could better tell what was wrong?
   - B. What are two things that could be wrong with this machine?

4. You are talking to the operator of an AC belt starter. The operator says this to you, "When I shut it off, it won't start up again.
   - A. What are the two most important things you can ask?
   - B. What are two things that could be wrong with the belt starter?

5. You are talking to the operator of an AC belt starter. The operator says this to you, "It runs too slow."
   - A. What are the two most important things you can ask?
   - B. What are two things that could be wrong with the belt starter?

STUDENT COMPETENCY SHEET #1

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

COMPETENCY STATEMENT: TROUBLESHOOTS AC/DC SOLID STATE PANEL BY SPECIFYING PROBABLE CAUSES FOR MALFUNCTIONS, RECOMMENDING SERVICE PROCEDURES, AND LOCATING AND CORRECTING FAULTS.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL TROUBLESHOOT AN AC/DC SOLID STATE PANEL.

CONDITIONS: YOU WILL BE TOLD TWO OR THREE PROBLEMS FOR AN AC/DC SOLID STATE PANEL. YOU HAVE THESE ITEMS TO WORK WITH: AC/DC - SOLID STATE PANEL, VOM, HANDTOOLS, SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, SPECIFICATIONS CHART, AND TROUBLESHOOTING GUIDE. YOU HAVE 30 MINUTES TO CORRECT EACH PROBLEM.

STANDARD: THIS IS HOW WELL YOU MUST DO:

1. FOR EACH PROBLEM YOU MUST LIST SOME CAUSES.
2. FOR EACH CAUSE YOU LIST YOU MUST LIST A REPAIR OR SERVICE PROCEDURE.
3. YOU MUST CORRECT EACH PROBLEM AND TAKE THE METER READINGS THAT SHOW THAT THE PANEL WORKS THE WAY IT SHOULD.
4. YOU MUST WORK SAFELY AND NOT DAMAGE TOOLS OR PARTS.
5. YOU MUST CORRECT EACH PROBLEM IN 30 MINUTES.

LEARNING ACTIVITIES:

1. IF YOUR INSTRUCTOR TELLS YOU, REVIEW STUDENT HANDOUT #1, "TRACING PULSE, AC/DC SOLID STATE PANEL."
2. GET THE SPECIFICATIONS CHART: AC/DC SOLID STATE PANEL FROM THE INSTRUCTOR. READ IT AND DO THE PROBLEMS AT THE END OF IT.
3. GET THE TROUBLESHOOTING GUIDE: AC/DC SOLID STATE PANEL FROM THE INSTRUCTOR. READ IT AND DO THE PROBLEMS AT THE END OF IT.
4. YOUR INSTRUCTOR HAS SOME TROUBLESHOOTING PROBLEMS FOR THE AC/DC SOLID STATE PANEL. GO GET ONE AND COMPLETE IT.
5. COMPLETE AS MANY TROUBLESHOOTING PROBLEMS AS YOUR INSTRUCTOR TELLS YOU TO.
6. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

SPECIFICATIONS CHART
AC/DC SOLID STATE PANEL

Unit: 14 Troubleshooting, AC/DC Solid State

I. Power Transformer

A. Primary Voltage: 440-480 AC Volts 30
B. Secondary Voltage: 120-208 AC Volts 30
C. Phasing Required: Yes, Both
D. Phasing Procedure: Left to right, top to bottom; Black, White, Red

II. Control Transformer

A. Primary Voltage: 440-480 AC Volts 30
B. Secondary Voltage: 120 AC Volts 10
C. Phasing Required: Yes, L11 and L12

III. SCR Bridge

A. Low Slow: 120 AC Volts 30 Rectified: 70 DC Volts
B. Low Fast: 120 AC Volts 30 Rectified: 165 DC Volts
C. High Slow: 208 AC Volts 30 Rectified: 140-150 DC Volts
D. High Fast: 208 AC Volts 30 Rectified: 275 DC Volts
E. Phasing Required: Yes, same as Power Transformer Secondary

IV. Firing Package

A. Input: 440-480 AC Volts 30
B. Output: 24 DC Volts
C. Phasing Required: Yes, left to right, Red, Black, White

D. SCR Gate Circuit: (1 and 2) (3 and 4) (5 and 6)
(19 and 20) (21 and 22) (23 and 24)

1. Low Slow: 0.5 to 1.0 DC Volts
2. Low Fast: 1.0 to 2.0 DC Volts
3. High Slow: 0.5 to 1.0 DC Volts
4. High Fast: 1.0 to 2.0 DC Volts

V. Logic Box

A. AC Input: 120 AC Volts 1Ø
B. AC Output: 120 AC Volts 1Ø
C. DC Output: 8 to 10 DC Volts

Problems

Take your VOM and go to the AC/DC Solid State Panel. Make the following readings and write them down. Show your paper to the instructor when you are done.

Power Transformer, secondary voltage __________ Volts
Control Transformer, secondary voltage __________ Volts
SCR Bridge, high slow setting __________ Volts
Firing Package, output __________ Volts
Firing Package, SCR gate Circuit, low slow __________ Volts
Logic Box, AC input __________ Volts
Logic Box, AC output __________ Volts
Logic Box, DC output __________ Volts

TROUBLESHOOTING GUIDE
AC/DC SOLID STATE PANEL

Unit: 14 Troubleshooting, AC/DC Solid State

Condition	Procedure
Traction circuit Contactors Inoperative	1. open, 3CB, Bridge Breaker; read 120 AC volts on Logic Box; Terminal #8 to #2.
	2. Check travel adjustment on Foot Switch.
Note*	* Pump Motor must be running:
No voltage	3. Read 120 AC volts from Pump interlock to Logic Box.
	4. Check connecting wire from switch to Logic Box input.
Yes voltage	5. Read 120 AC volts from that coil Terminal output, to #2.
No voltage	6. Power OFF: check contactor coil resistance: size #2 contactor read 25 ohms: size #3 read 7 ohms.
	7. If Resistance = "0," look for short from output terminal to Point #2 or shorted coil:
	8. Resistance High; check, for open coil, loose connection, faulty electrical interlock, or mechanical interlock.
All OK	9. Replace Logic Box.

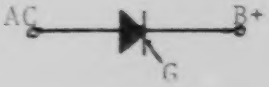
Condition	Procedure
Traction Circuit contactors stay closed when switch is OFF	10. Open: 1CB and 3CB; check for input signal to contactors; should be zero volts. 11. Look for short on output side of Logic Box to contactor in question. 12. Look for shorted switches and stray wiring. 13. If all checks out, replace Logic Box.
Machine will not move	14. Check all AC input. 15. IF ok, check Logic Box DC voltage, Terminal #69 (+) to #2 (-). Should = about zero volts when tram levers and foot switch off.
No voltage	16. Disconnect leads to Terminals #68 and #69; Power OFF: measure resistance between the two leads; ohmmeter should read maximum resistance or infinity. If the meter reads or shows continuity, one or both overloads must be replaced.
Yes Voltage	17. Reconnect leads. Power ON: close foot switch and tram switch. Replace Logic Box.
No Voltage	18. Check for mechanical binding or anything that would cause motors to overload. If overloading occurs, the voltage between Terminal #69 and #2 will increase to about 9 DC volts.

Condition	Procedure
Electrical check OK	19. Check Forward and Reverse contact tips. 20. If these check OK, check motor circuit wiring.
Wrong Voltage or we read voltage in both Slow and High Speeds	21. Check AC power wiring for proper phasing and tightness. 22. Check voltage of Primary and Secondary on Power Transformer. 23. All wiring and Phase to Phase voltages OK, check high voltage to Firing Package; should be at Line Voltage and equal between Phases. 24. If not, check wiring back to Transformer. 25. If Line Voltage to Power Transformer is OK and voltages of Transformer do not meet specifications, replace Power Transformer.
Note: Check for zero readings on less than 10 volt scale	All previous checks OK; make the following DC voltage checks: Open 3CB (Bridge Breaker), Deadman Switch Closed

Tram Lever -	1. OFF	2. L.S.	3. L.F.	4. H.S.	5. H.F.
26. #62 and #162 to #65 -	0	14	17	14	17
27. #63 and #163 to #65 -	0	0	18	0	18

DC Voltage Readings

Condition	Procedure
Bad reading	28. Check for 24 DC volts between #12 and #13 at Firing Package.
No voltage	29. Replace Firing Package.
Yes, 24 volts	30. Replace Logic Box.
If all previous checks OK	Check SCR gate voltages on Firing Package terminals; 1 (+) and 2 (-); 3 (+) and 4 (-) 5 (+) and 6 (-); 20 (+) and 19 (-); 22 (+) and 21 (-); 24 (+) and 23 (-). 31. LS and HS, read 0.3 to 0.5 DC volts between points indicated. 32. LF and HF, read 1.0 to 2.0 DC volts same points. If voltage of SCR gate terminals do not agree with specifications, replace Firing Package.
	Power Diodes and SCRs
If the DC output of Power circuit is still bad or CB-3 trips under load Use RX1000 on ohmmeter for all readings	Make the following resistance checks: Shut off all power to the machine; make sure Bridge Breaker is open: 33. + lead on B- and - lead on each AC input line; read 1.2 x 1K. 34. - lead on B- and + lead on each AC input line; read ∞ 35. + lead on B+ and - lead on each AC input line; read ∞ 36. - lead on B+ and + lead on each AC input line; read ∞

CONDITIONS	PROCEDURE
	37. + LEAD ON GATE AND - LEAD ON B+; READ .1 x 10
	38. - LEAD ON GATE AND + LEAD ON B+; READ .1 x 10
	39. + LEAD ON GATE AND - LEAD ON AC INPUT LINE FOR THAT SCR = ∞
	40. - LEAD ON GATE AND + LEAD ON AC INPUT LINE FOR THAT SCR = ∞
IF READINGS ARE NOT CORRECT, CHECK DC OUTPUT WIRING; IF WIRING OK, CHECK INDIVIDUAL SCR IN SAME PHASE AS SHORTED DIODE; DO NOT ASSUME THAT THE SCR IS BAD	RESISTANCE CHECKS ON SCR IN SAME PHASE AS SHORTED DIODE *LEGEND: AC IS AC INPUT LINE B+ IS SCR CATHODE G IS SCR GATE 
	41. + LEAD ON AC AND - LEAD ON B+, READ 1.2 x 1K
	42. + LEAD ON B+ AND - LEAD ON AC, READ ∞
	43. + LEAD ON G AND - LEAD ON B+, READ ZERO
	44. + LEAD ON B+ AND - LEAD ON G, READ ZERO
	45. + LEAD ON AC AND - LEAD ON G, READ 1.2 x 1K
	46. + LEAD ON G AND - LEAD ON AC, READ ∞
EXCESSIVE WEAR ON D1, S1 FORWARD OR REVERSE CONTACTORS	47. PUSH TRAM LEVER TO FAST POSITION AND THEN PUSH FOOTSWITCH AND WATCH FOR MACHINE MOVEMENT.

Condition	Procedure
Yes, machine moves	48. Check wiring of 62 and 162 and 65 between Logic Box and Firing Package.
Wiring OK	49. Read zero volts (less than 10 volt scale) between 62 and 65 and 162 to 65.
If you read voltage	50. Replace Logic Box.
No, Machine does not move	51. If wear is on D and S contacts: switch from slow to fast tram and watch input and output lights. (Red and Amber): It should take about 1/2 second after Red input (HSR light) goes on, that Delta Amber light goes out, and Amber star light goes on.
	52. Also, reverse the procedure going from fast to slow: it should again take about 1/2 second for after HSR light goes out, the star light also goes out and the Delta light comes on.
No, lights do not work as described	53. Replace Logic Box.
Yes	54. Shut OFF power and check free wheeling diodes.

CONDITION		PROCEDURE
		CHECK FREE WHEELING DIODES WITH OHMMETER: HIGH READING IN ONE DIRECTION, LOW READING IN OPPOSITE DIRECTION: CHECK ON HIGH SCALE RX1000 OR HIGHER. FREE WHEELING DIODES ARE MOUNTED INDIVIDUALLY IN THEIR OWN HEAT SINKS.
IF DEFECTIVE		REPLACE DIODE(S)
IF WEAR IS ON FORWARD AND REVERSE	55.	CHECK FORWARD AND REVERSE AMBER LIGHTS ON LOGIC BOX; THEY SHOULD REMAIN ON ABOUT ONE SECOND AFTER TRAM LEVER IS RELEASED (WHICH IS INDICATED WHEN RED INPUT LIGHT GOES OUT).
LIGHTS DO NOT WORK AS DESCRIBED	56.	REPLACE LOGIC BOX.
YES, LIGHTS DO WORK AS DESCRIBED	57.	CHECK FREE WHEELING DIODES AS PREVIOUSLY DESCRIBED IF YOU HAVE NOT ALREADY DONE SO.

PROBLEMS

Take your meters and go to the AC/DC Solid State Panel. Do the following procedures from the Troubleshooting Guide: AC/DC Solid State Panel. Write down any readings you get. Show your paper to the instructor when you are done.

Reading

1. Procedure #1 ________
2. Procedure #5 ________
3. Procedure #10 ________
4. Procedure #15 ________
5. Procedure #26 ________

____

____

____

____

6. Procedure #35 ________
7. Procedure #40 ________
8. Procedure #44 ________
9. Procedure #49 ________
10. Procedure #52 ________

TROUBLESHOOTING PROBLEMS #1-#8

Unit: 14 Troubleshooting, AC/DC Solid State

Read this:

While doing any of the troubleshooting problems, follow all these safety rules.

1. Know what voltage you intend to measure before connecting the voltmeter leads.
2. If you do not know what a voltage reading should be set the meter for the highest voltage reading possible.
3. Never connect an ohmmeter in a "live" circuit.
4. Do not touch the leads or bare probes of the meter leads when measuring any voltage. Hold only the insulated handles in the center between thumbs and index fingers.
5. Never touch any part of the panel when it is energized. If you have to check a component for movement, such as a line starter, disconnect the power unit.
6. When in doubt, ask the instructor.

When doing the troubleshooting problems, follow these general procedures.

1. Use the Specification Chart: AC/DC Solid State Panel and schematic and wiring diagrams to get correct voltage readings and for finding points of measurements.
2. Follow all the instructions and answer all the questions with each problem.

PROBLEM #1

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: DETERMINE IF THE VOLTAGE IS CORRECT TO THE LOGIC BOX.

ACTIVITIES:

(A) RECORD YOUR MEASUREMENT. ________________ VOLTS.

(B) RECORD THE EXPECTED VOLTAGE ________________ VOLTS.

(C) WRITE THE TERMINAL NUMBERS THAT YOU TOUCHED WITH THE VOLTMETER PROBES: #_____ AND # ____.

(D) WRITE, AS BRIEFLY AS YOU CAN, WHAT YOU WOULD RECOMMEND TO CORRECT THE PROBLEM.

(E) DISCONNECT THE POWER TO THE PANEL AND DO THE REPAIR THAT YOU RECOMMENDED.

(F) HAVE THE INSTRUCTOR CHECK YOUR REPAIR.

(G) TURN THE POWER ON TO THE PANEL AFTER YOUR REPAIR HAS BEEN CHECKED BY THE INSTRUCTOR.

(H) REPEAT THE MEASUREMENT AND RECORD YOUR READING __________ VOLTS.

(I) TURN OFF ALL POWER TO THE PANEL.

PROBLEM #2

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: D1 AND S1 CONTACTS WILL NOT CLOSE. DETERMINE THE CAUSE.

ACTIVITIES: RECORD:

(A) WHAT POINTS DID YOU CHECK? (USE AS MANY SPACES AS NEEDED)

(1) ______________________ VOLTAGE OBTAINED ______________

(2) ______________________ VOLTAGE OBTAINED ______________

(3) ______________________ VOLTAGE OBTAINED ______________

(B) WHAT CAUSED THE PROBLEM?

(C) RECOMMENDED REPAIR:

TURN OFF ALL POWER TO THE PANEL AND

(D) DO THE REPAIR THAT YOU RECOMMENDED.

(E) HAVE THE INSTRUCTOR VERIFY THE REPAIR.

(F) TURN ON THE POWER TO THE PANEL AFTER THE INSTRUCTOR CHECKS YOUR WORK.

(G) DID YOUR REPAIR AGREE WITH YOUR RECOMMENDATION? ______________

(H) IF THE REPAIR IS SATISFACTORY, TURN OFF ALL POWER TO THE PANEL.

(I) IF THE REPAIR IS NOT COMPLETE OR THE PANEL DOES NOT FUNCTION, PROCEED NO FURTHER, BUT CALL THE INSTRUCTOR.

PROBLEM #3

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: TRACTION CIRCUIT CONTACTORS WILL NOT OPEN WHEN THE SWITCH IS OFF. DETERMINE WHAT IS WRONG.

ACTIVITIES:

(A) LIST THE PLACES THAT YOU WOULD CHECK FOR VOLTAGE.

(1)

(2)

(3)

(B) WHAT DO YOU THINK IS WRONG AND HOW WOULD YOU REPAIR IT?

TURN OFF ALL POWER:

(C) MAKE THE REPAIR THAT YOU RECOMMEND.

(D) HAVE THE INSTRUCTOR CHECK YOUR REPAIR.

TURN POWER BACK ON AFTER THE INSTRUCTOR HAS CHECKED YOUR WORK.

(E) WHAT DID YOU FIND WRONG?

(F) TURN OFF POWER TO PANEL.

PROBLEM #4

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: BRIDGE BREAKER KICKS OFF WHEN TRAM MOTORS ARE STARTED. DETERMINE THE CAUSE.

ACTIVITIES:

(A) WHAT DO YOU THINK THE PROBLEM IS?

(B) HOW WOULD YOU CORRECT THE PROBLEM?

SHUT OFF ANY POWER TO THE MACHINE.

(C) BASED ON YOUR DIAGNOSIS, REPAIR THE PROBLEM.

(D) AFTER YOU HAVE LOCATED AND REPAIRED THE CAUSE OF THE PROBLEM, HAVE THE INSTRUCTOR CHECK YOUR WORK.

(E) AFTER YOUR WORK HAS BEEN CHECKED, TURN THE POWER ON AND VERIFY YOUR WORK BY OPERATING THE PANEL.

(F) TURN OFF ALL POWER.

PROBLEM #5

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: LEFT HAND TRAM MOTOR WILL NOT RUN. DETERMINE THE CAUSE.

ACTIVITIES:

(A) WHAT POINTS WOULD YOU MEASURE FIRST?

(1)

(2)

(3)

(B) WHAT DO YOU THINK IS WRONG?

(C) YOUR RECOMMENDATION FOR REPAIR.

TURN OFF POWER.

(D) MAKE THE REPAIR

(E) HAVE THE INSTRUCTOR CHECK YOUR REPAIR.

(F) VERIFY THE REPAIR BY OPERATING THE PANEL.

PROBLEM #6

Unit: 14 Troubleshooting, AC/DC Solid State

Problem: Tram motors will not start. Determine the cause.

Activities:

(a) List the points where you would measure for voltage.

(1)

(2)

(3)

(b) What is the problem?

(c) What has to be done to correct the problem?

Turn off all power.

(d) Do the repair that you recommend.

(e) Have the instructor check your repair.

Turn on power

(f) Verify that the problem has been corrected by operating the panel.

PROBLEM #7

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: MACHINE WILL NOT MOVE. DETERMINE THE CAUSE.

ACTIVITIES:

(A) LIST THE FIRST THREE POINTS THAT YOU WILL CHECK, AND WHAT VOLTAGE YOU EXPECT TO READ AT THOSE POINTS.

(1) ANTICIPATED VOLTAGE __________

(2) ANTICIPATED VOLTAGE __________

(3) ANTICIPATED VOLTAGE __________

(B) LIST THE ACTUAL VOLTAGE READINGS THAT YOU READ AT THE POINTS YOU HAVE LISTED:

VOLTAGE __________

VOLTAGE __________

VOLTAGE __________

(C) WHAT DO YOU THINK IS WRONG?

TURN OFF POWER

(D) DO THE REPAIRS THAT YOU RECOMMEND.

(E) HAVE THE INSTRUCTOR CHECK YOUR REPAIR.

(F) VERIFY THE REPAIR BY OPERATING THE PANEL.

PROBLEM #8

UNIT: 14 TROUBLESHOOTING, AC/DC SOLID STATE

PROBLEM: D1 CONTACTOR WILL NOT CLOSE. DETERMINE THE CAUSE.

ACTIVITIES:

(A) LIST THE POINTS THAT YOU WOULD MEASURE FIRST AND INDICATE THE VOLTAGE YOU EXPECT TO FIND AT THOSE POINTS.

(1) VOLTAGE ____________

(2) VOLTAGE ____________

(3) VOLTAGE ____________

(B) LIST ACTUAL VOLTAGES MEASURED.

VOLTAGE ____________

VOLTAGE ____________

VOLTAGE ____________

(C) WHAT DO YOU THINK THE PROBLEM IS?

TURN OFF ALL POWER.

(D) MAKE THE REPAIR THAT YOU THINK WILL CORRECT THE PROBLEM.

(E) HAVE THE INSTRUCTOR CHECK YOUR REPAIRS.

(F) VERIFY THE REPAIR BY OPERATING THE PANEL.

STUDENT COMPETENCY SHEET #1

UNIT: 15 SCHEMATICS: SOLID STATE, BATTERY POWERED

COMPETENCY STATEMENT: TRACES PULSE THROUGH A BATTERY-POWERED SOLID STATE SYSTEM AND EXPLAINS OPERATION.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. TRACE WITH A PENCIL THE PULSE FLOW ON BATTERY-POWERED SOLID STATE SYSTEM DIAGRAMS.
2. EXPLAIN THE OPERATION OF THE SYSTEM YOU TRACE TO THE INSTRUCTOR.

CONDITIONS: YOU HAVE BATTERY-POWERED SOLID STATE SYSTEM DIAGRAMS. YOU MAY NOT USE REFERENCES. YOU HAVE 30 MINUTES TO DO THIS.

STANDARD: ALL YOUR TRACING AND EXPLAINING MUST BE CORRECT. THIS MEANS THAT THE SYSTEM REALLY WOULD WORK LIKE YOU SAY.

LEARNING ACTIVITIES:

1. YOUR INSTRUCTOR WILL GIVE A DEMONSTRATION ON HOW THE SOLID STATE, BATTERY POWERED PANEL OPERATES. GO TO THE DEMONSTRATION.
2. GET STUDENT HANDOUT #1,"SCHEMATICS: SOLID STATE, BATTERY POWERED," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
3. GET CLEAN COPIES OF THE BATTERY POWERED, SOLID STATE SYSTEM DIAGRAM. TRACE ALL THE STEPS LISTED IN STUDENT HANDOUT #1. AFTER YOU TRACE EACH STEP HAVE THE INSTRUCTOR CHECK YOUR WORK. CHANGE ANYTHING THAT IS WRONG.

4. GET ANOTHER STUDENT. EXPLAIN WHAT HAPPENS DURING EACH STEP OF OPERATION FOR THE CIRCUITS ON THE BATTERY-POWERED, SOLID STATE SYSTEM DIAGRAM.
5. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1

UNIT: 15 SCHEMATICS: SOLID STATE, BATTERY POWERED

THE DIAGRAM

TAKE A MOMENT TO LOOK OVER THE SOLID STATE DIAGRAM FOR A BATTERY-POWERED SYSTEM. LOOK AT ALL THE COMPONENTS. LOOK AT THE GENERAL LAYOUT OF THE DIAGRAM.

ALL THE COMPONENTS NEEDED FOR THE MACHINE TO FUNCTION ARE NOT SHOWN ON THE DIAGRAM. ONLY THOSE NEEDED TO EXPLAIN CIRCUIT OPERATION ARE SHOWN. THE ELECTRONIC CONTROL MODULE (LOGIC UNIT) HAS MOST OF THE CIRCUITS WE HAVE STUDIED SO FAR.

THE REVERSE AND FORWARD (REV. AND FWD.) SWITCH HAS ONLY ONE FUNCTION. IT CLOSES THE FORWARD AND/OR REVERSE CONTACTORS DEPENDING ON WHICH DIRECTION YOU WANT THE MACHINE TO GO. FIND THE CONTACTORS ON THE DIAGRAM. FIND THE BYPASS CONTACTOR. THE BATTERY SYMBOLS SHOW THE VOLTAGE SUPPLY. WE KNOW THAT WE ARE TALKING ABOUT DIRECT CURRENT.

THERE ARE THREE SCRs IN THE SYSTEM. THEY WILL OPERATE IN A DEFINITE FIRING ORDER. THE FIRING ORDER IS LIKE THIS:

FIRST - SCR #2 WHICH IS THE "OFF" SCR
SECOND - SCR #1 "MAIN" SCR
THIRD - SCR #3 "REVERSAL" SCR

LIKE WITH YOUR CAR, THE SCRs IN THIS CIRCUIT HAVE A DEFINITE "FIRING ORDER." IT DOES NOT CHANGE, JUST AS THE FIRING ORDER IN YOUR CAR DOES NOT CHANGE. THE THING THAT DOES

CHANGE IS THE SPEED OF THE FIRING ORDER. THE MORE GAS YOU GIVE YOUR CAR, THE FASTER THE "FIRING ORDER" TAKES PLACE. THE MORE WE PUSH THE ACCELERATOR OF THE SOLID STATE, BATTERY POWERED PANEL, THE FASTER THE SCR "FIRING ORDER" WILL OCCUR. THIS DELIVERS A HIGHER VOLTAGE TO THE MOTOR.

FIND THE COMMUTATION COIL "L2", AND THE CAPACITOR. THEY MAKE UP A RESONATING CIRCUIT IN WHICH THE CAPACITOR CHARGE IS DELIVERED TO THE COIL AND THE COIL IN TURN DELIVERS THE CHARGE TO THE OTHER PLATE OF THE CAPACITOR. WHEN THIS OCCURS THE CAPACITOR'S POLARITY IS REVERSED. THE CAPACITOR IS ALSO CHARGED TO A HIGHER VOLTAGE DUE TO WHAT WE EARLIER CALLED "INDUCTIVE KICK".

FIND THE TWO DIODES IN THE DIAGRAM. THEY ARE CALLED THE PLUGGING/FLYWHEEL DIODES. THE LEFT DIODE IS USED FOR FORWARD OPERATION AND THE RIGHT DIODE IS USED FOR REVERSE OPERATION OF THE MOTOR.

WHEN THE CURRENT FLOWING THROUGH THE ARMATURE AND FIELD WINDINGS OF A MOTOR IS INTERRUPTED THEIR MAGNETIC FIELDS COLLAPSE. THE COLLAPSING MAGNETIC FIELDS CAUSE INDUCED CURRENT TO FLOW IN THE MOTOR WINDINGS. ALTHOUGH THE INDUCED CURRENT ONLY FLOWS FOR A BRIEF MOMENT THE FLYWHEEL DIODE LETS US PUT IT TO GOOD USE.

IN THE SCR SYSTEM CURRENT THROUGH THE MOTOR IS INTERRUPTED

400 TIMES PER SECOND. EACH TIME IT IS INTERRUPTED THE FLYWHEEL DIODE PERMITS THE INDUCED CURRENT TO CIRCULATE IN THE MOTOR WINDING. THIS KEEPS THE MOTOR RUNNING WHILE THE BATTERY IS DISCONNECTED. SINCE THE BATTERY SUPPLIES ENERGY TO THE MOTOR PART OF THE TIME, AND INDUCTION SUPPLIES ENERGY PART OF THE TIME, THE BATTERY CHARGE WILL LAST MUCH LONGER.

OPERATION

THE ENTIRE PURPOSE OF THE BATTERY-POWERED SYSTEM IS TO PROVIDE A VERY FAST MEANS OF SWITCHING CURRENT ON AND OFF. THE SCR IS THE SOLID STATE SWITCH THAT MAKES THIS HAPPEN. KEEP IN MIND THAT THE TIME FROM WHEN THE FIRST PULSE STARTS TO WHEN IT STOPS IS LESS TIME THAN IT TAKES YOU TO BLINK YOUR EYES.

LOOK AT THE DIAGRAMS AS YOU READ EACH STEP. THE CONDITIONS DURING OPERATION ARE LIKE THIS:

STEP 1. FORWARD REVERSE SWITCH IN FORWARD POSITION.

(A) FORWARD CONTACTORS CLOSE

(B) MOTOR IS NOW CONNECTED TO THE SOLID STATE CONTROL PANEL.

(C) SCRS ARE NOT CONDUCTING AT THIS TIME

STEP 2. DEPRESS ACCELERATOR

(A) PULSE TRIGGERED TO SCR #2 FROM LOGIC UNIT

(B) SCR #2 CONDUCTS AND CHARGES CAPACITOR

STEP 3. CAPACITOR CHARGED

(A) CURRENT THROUGH SCR #2 FALLS TO ZERO

(B) SCR #2 TURNS OFF

(C) LOGIC UNIT PULSES SCR #1

Step 4. Main SCR #1 fires into conduction

(A) Current flows from battery through SCR #1, through motor and back to battery

(B) Motor starts

(C) Logic Unit pulses SCR #3

Step 5. SCR #3 Conducts

(A) The capacitor begins to discharge through the coil, SCR #3, and SCR #1.

(B) A magnetic field is produced in the coil winding.

Step 6. Capacitor discharges all of its stored energy.

(A) SCR #3 pulse has ended, but it continues to conduct the capacitor's discharge current.

(B) The capacitor has fully discharged.

(C) The magnetic field of the coil begins to collapse, charging the capacitor in the opposite polarity.

(D) The capacitor is now charged with the opposite polarity. Due to induction, the voltage of the charge is greater than the battery voltage.

(E) Induced current stops flowing when the capacitor is charged.

(F) SCR #3 no longer conducts and returns to a blocking state.

(G) SCR #1 is still conducting.

Step 7. SCR #2 Fires

(A) This connects the capacitor to SCR #1.

THE NEGATIVELY CHARGED PLATE OF THE CAPACITOR IS CONNECTED TO THE ANODE OF SCR #1. THE POSITIVE PLATE IS CONNECTED TO THE CATHODE OF SCR #1.

(B) THE CAPACITOR CAUSES A REVERSE BIASED VOLTAGE THAT IS HIGHER THAN THE BATTERY VOLTAGE TO BE APPLIED TO SCR #1.

(C) THIS HIGH REVERSED BIASED VOLTAGES CAUSES SCR #1 TO TURN OFF.

(D) SCR #2 STAYS IN CONDUCTION.

(E) THE CAPACITOR CHARGES THROUGH THE MOTOR TO ITS ORIGINAL POLARITY.

STEP 8. CAPACITOR FULLY CHARGED.

(A) WHEN THE CAPACITOR BECOMES FULLY CHARGED CURRENT FLOW STOPS. THIS CAUSES SCR #2 TO RETURN TO A BLOCKING STATE.

(B) THE MOTOR IS DISCONNECTED FROM THE BATTERY.

(C) INDUCED CURRENT CIRCULATES IN THE MOTOR WINDING.

(D) THE CIRCUIT IS PRIMED. IT IS READY TO DO THE SAME STEPS AGAIN.

STEP 9. ACCELERATOR PUSHED ALL THE WAY DOWN FOR FULL SPEED OPERATION.

(A) PULSING RATE INCREASES TO 400 PULSES PER SECOND.

(B) MOTOR VOLTAGE = 93 PERCENT OF THE BATTERY VOLTAGE.

(C) BYPASS CONTACTOR CLOSES. THIS SHORTS OUT THE

SCR CIRCUIT.

(D) MOTOR IS CONNECTED DIRECTLY TO THE BATTERY.

(E) ACCELERATION IS SMOOTH WHEN BYPASS CONTACTOR CLOSES.

ANSWER THE FOLLOWING QUESTIONS TO ENSURE YOUR UNDERSTANDING OF THE CIRCUIT:

1. WHAT CAUSES SCR #1 TO TURN OFF?

2. WHAT IS THE PURPOSE OF THE COMMUTATION COIL?

3. EXPLAIN WHAT HAPPENS TO THE FIRING SEQUENCE OF THE SCRs WHEN THE ACCELERATOR IS ALL THE WAY DOWN.

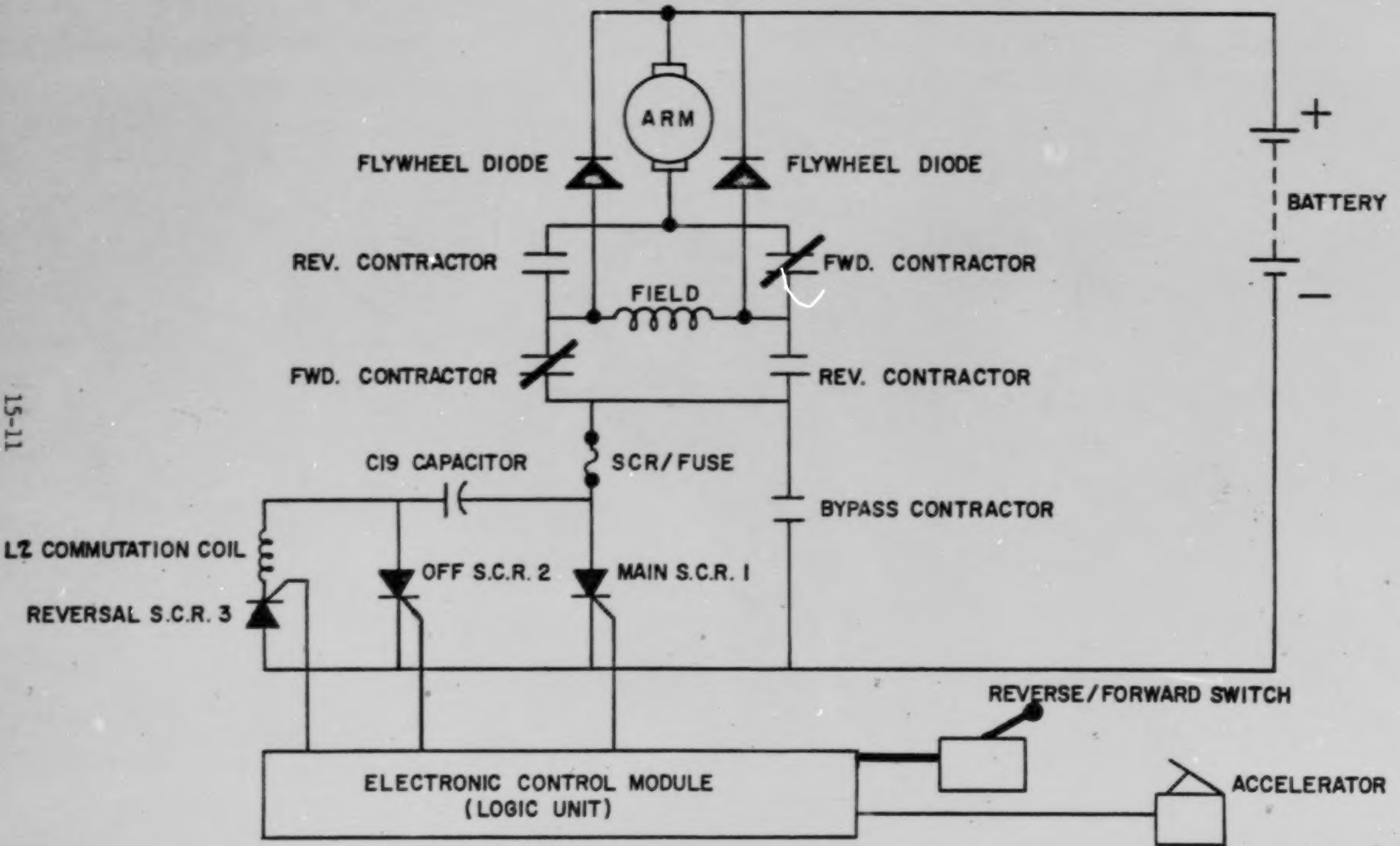
4. EXPLAIN WHY MOTOR CURRENT CONTINUES TO FLOW AFTER SCR #1 TURNS OFF.

5. NAME ONE PURPOSE OF SCR #2

6. WHY IS IT IMPORTANT THAT THE RIGHT-HAND PLATE OF THE CAPACITOR FIRST BE POSITIVE?

7. WRITE THE ORDER IN WHICH THE SCRs FIRE.

8. WHEN THE BYPASS CONTACTOR CLOSES, WHY DOESN'T THE MACHINE JERK AS IT GOES TO MAXIMUM SPEED?



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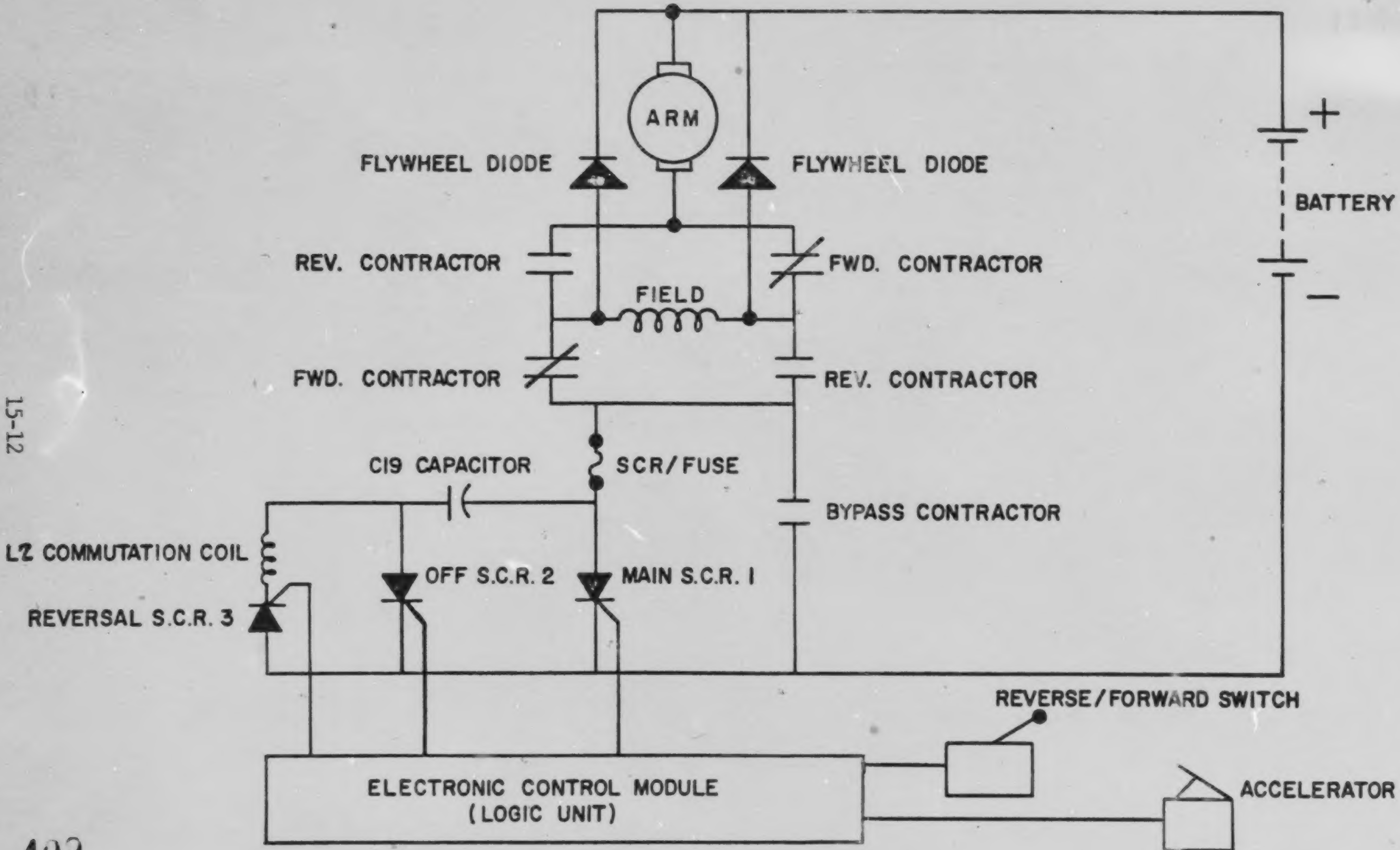
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 1

FORWARD REVERSE SWITCH IN FORWARD POSITION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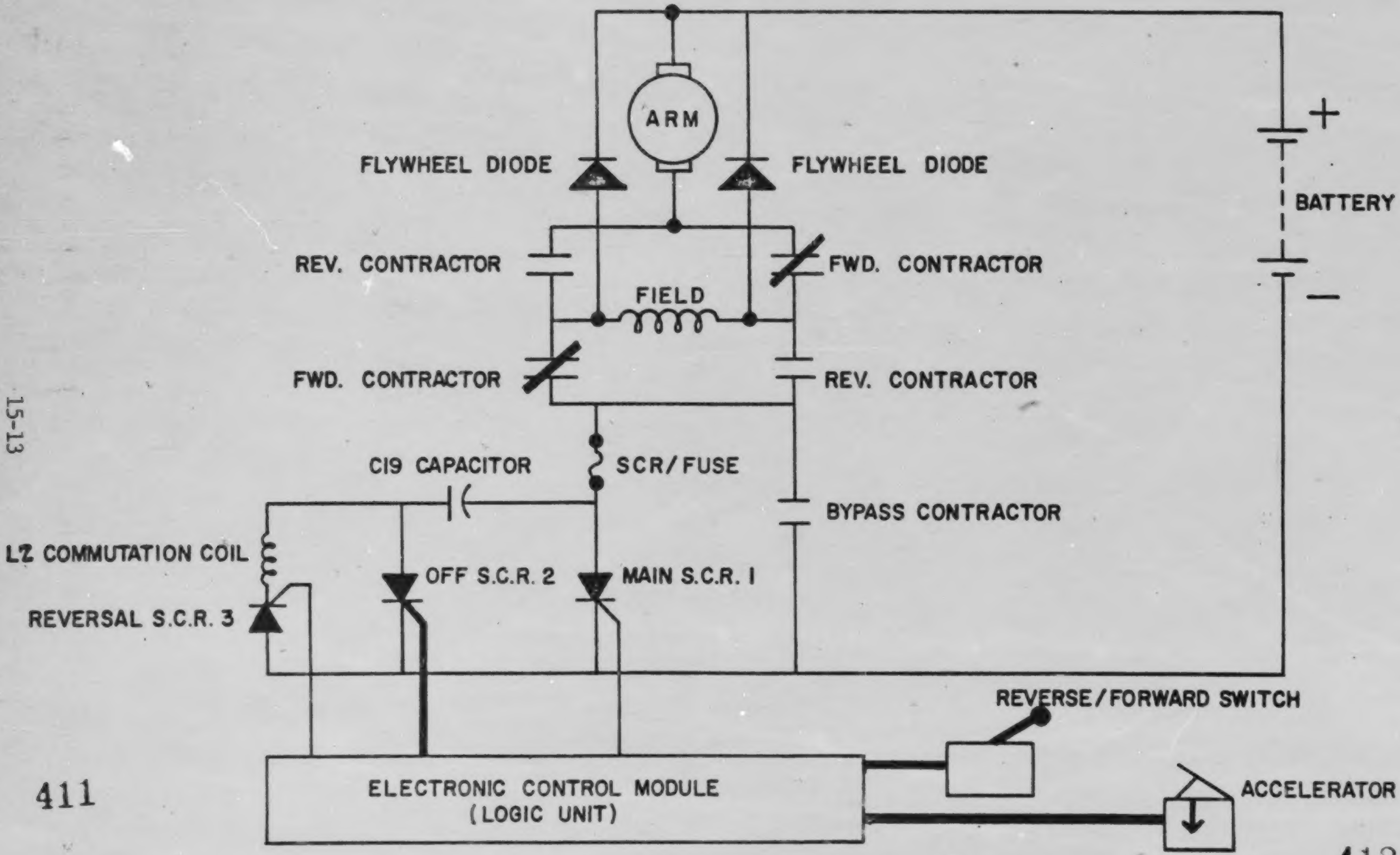
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MAIN S.C.R. 1
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REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

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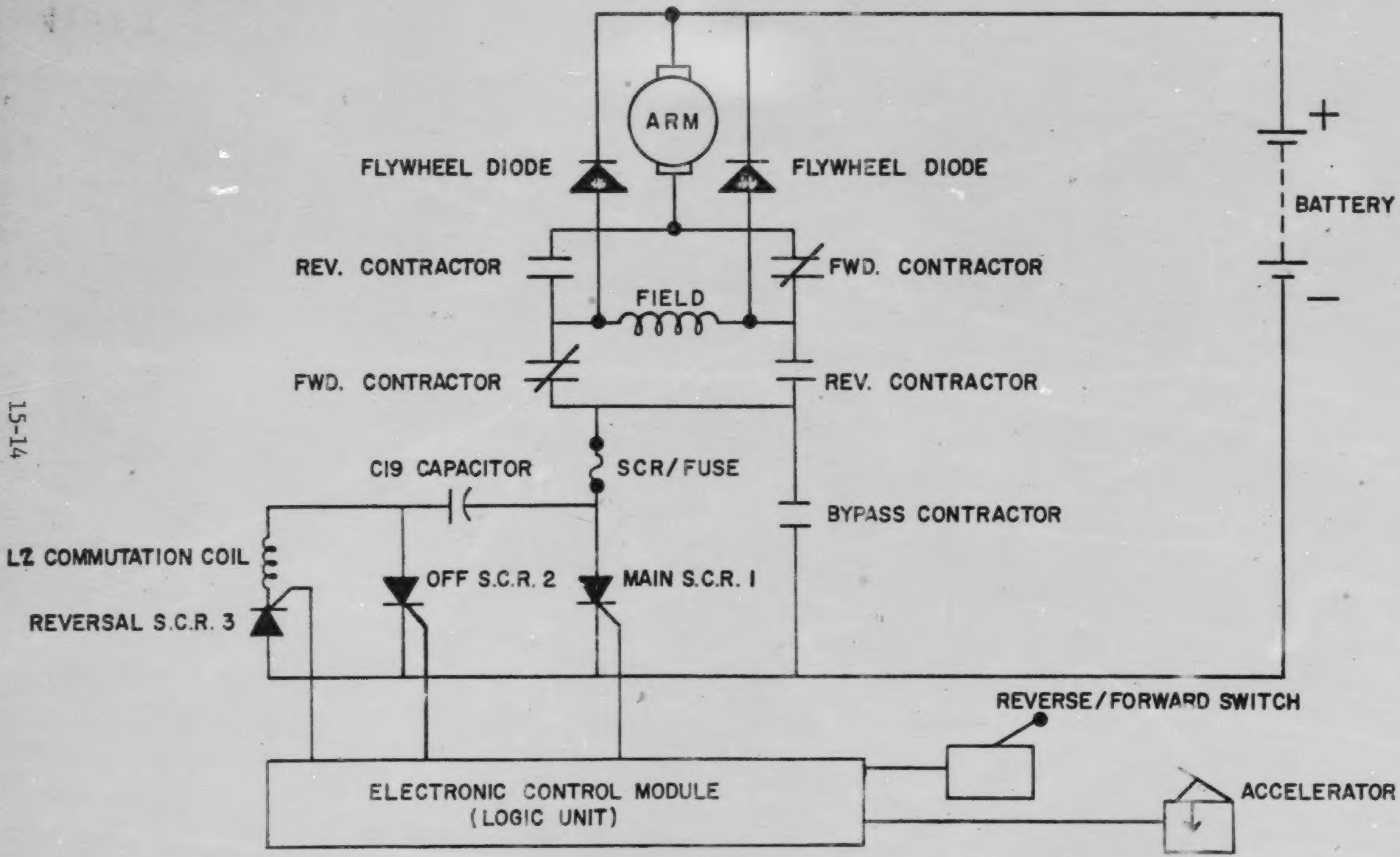
STEP 2A

DEPRESS ACCELERATOR

15-14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ELECTRONIC CONTROL MODULE
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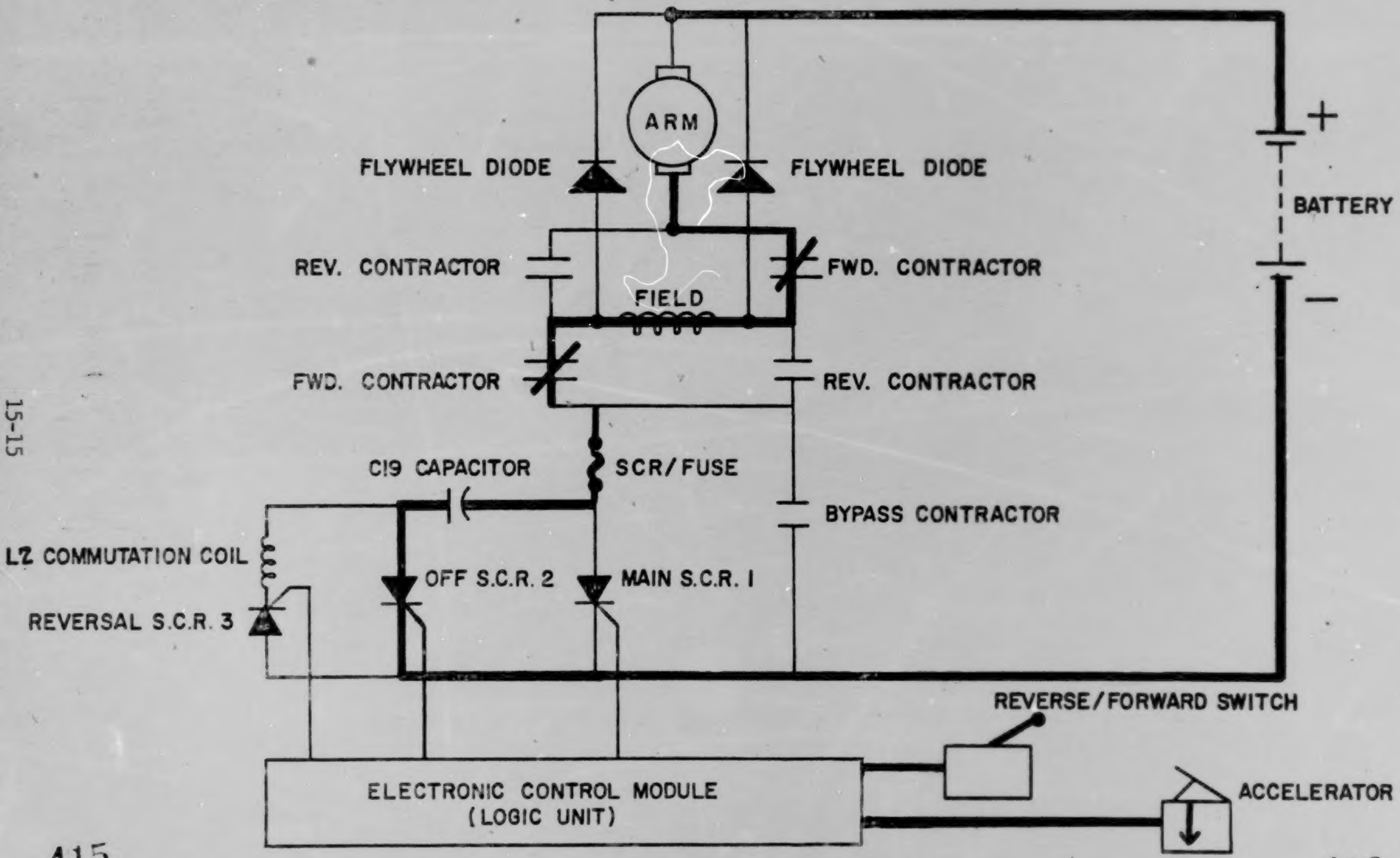
ACCELERATOR

STEP 2A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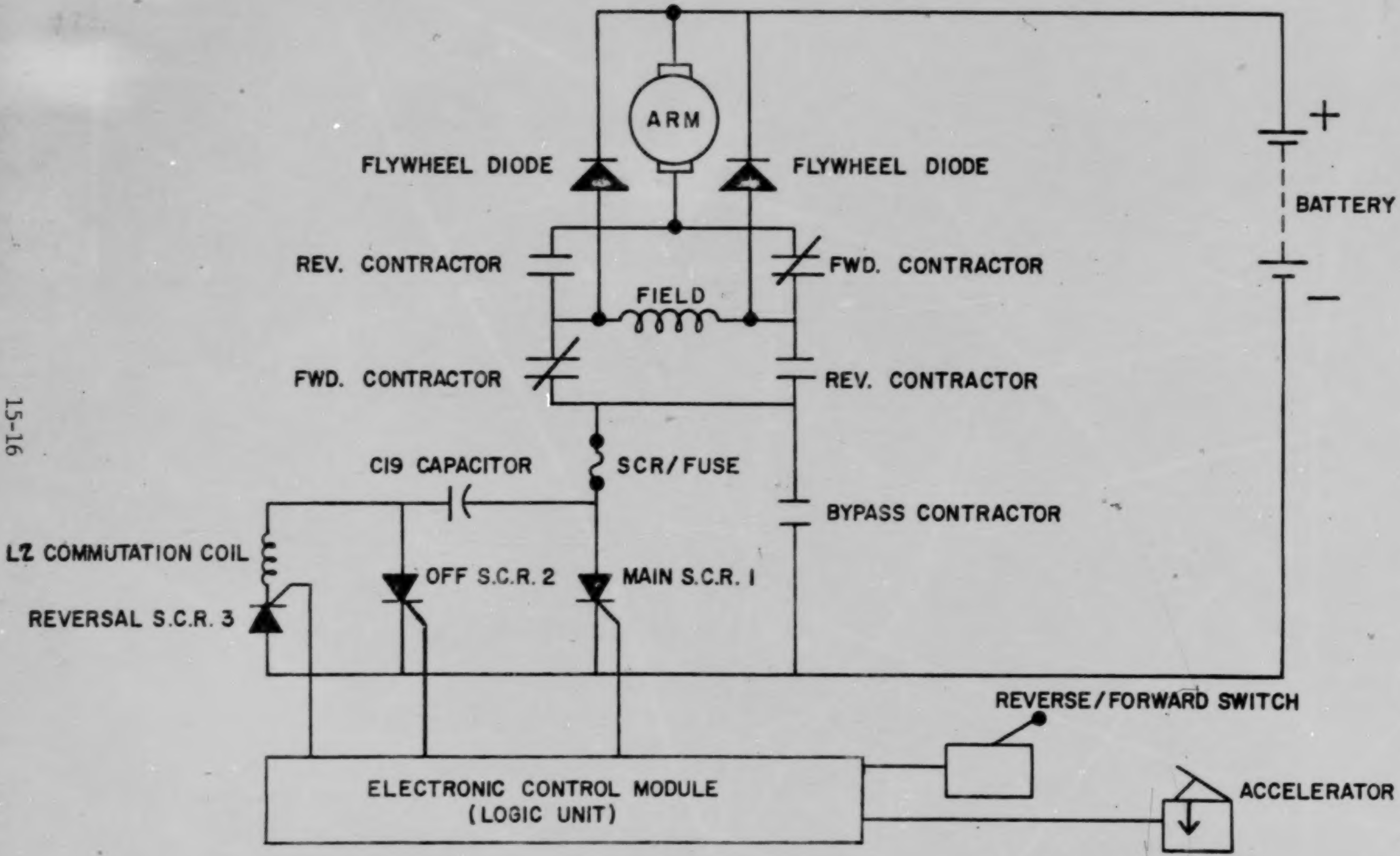
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 2B

SCR #2 CONDUCTS AND CHARGES CAPACITOR

15-16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ACCELERATOR

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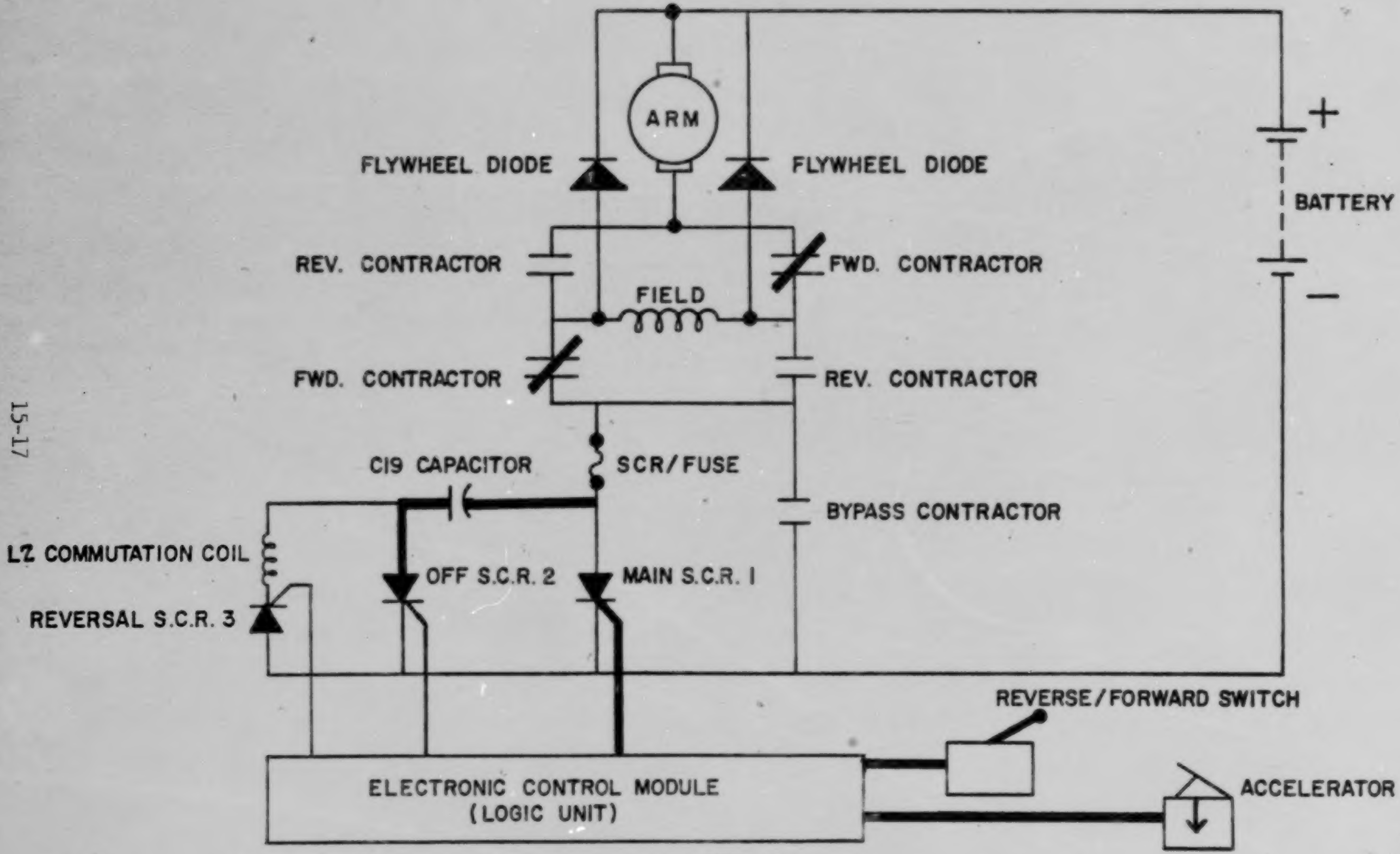
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REVERSE/FORWARD SWITCH
ACCELERATOR
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)

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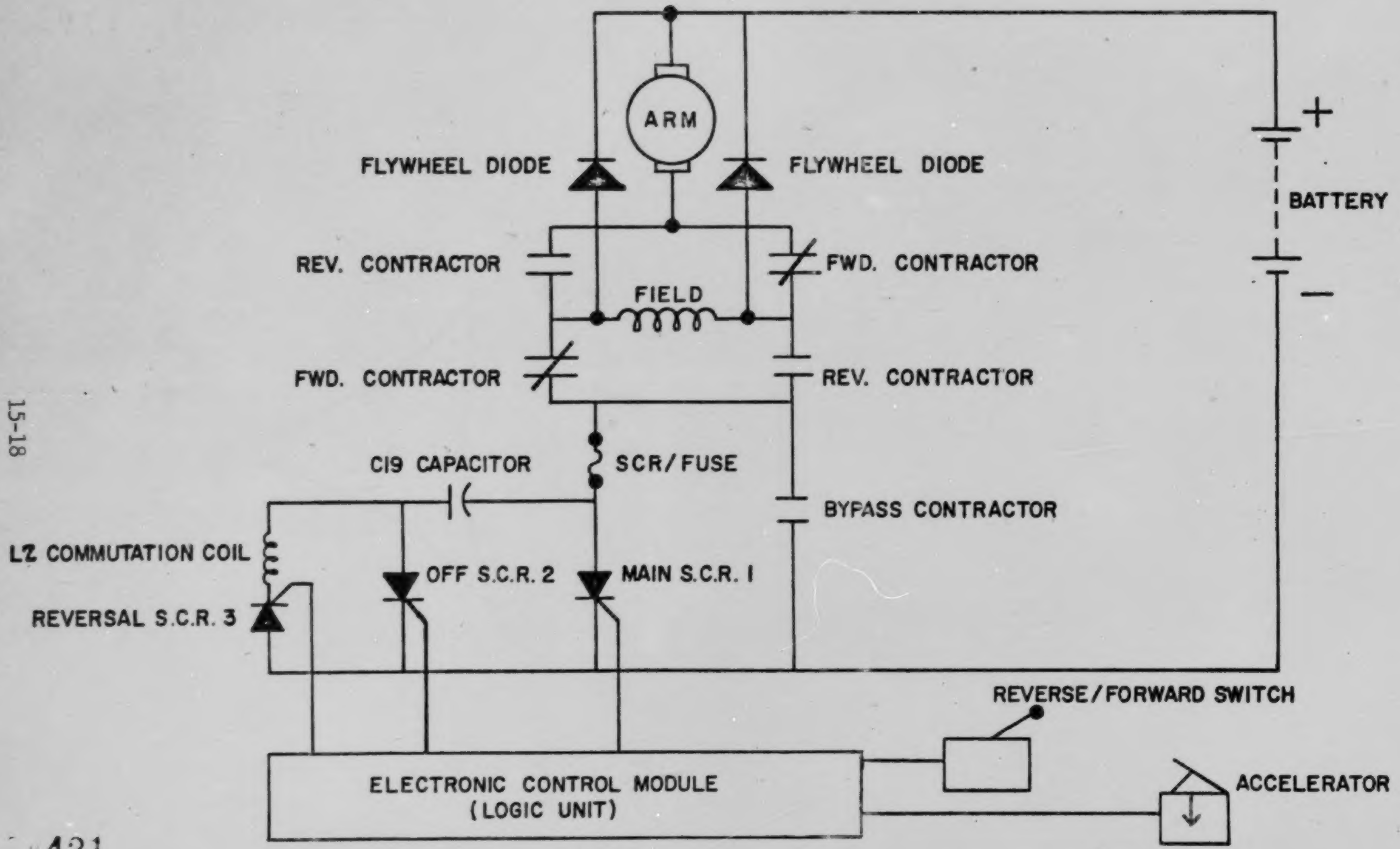
STEP 3

CAPACITOR CHARGED

SCR #1 [illegible]SES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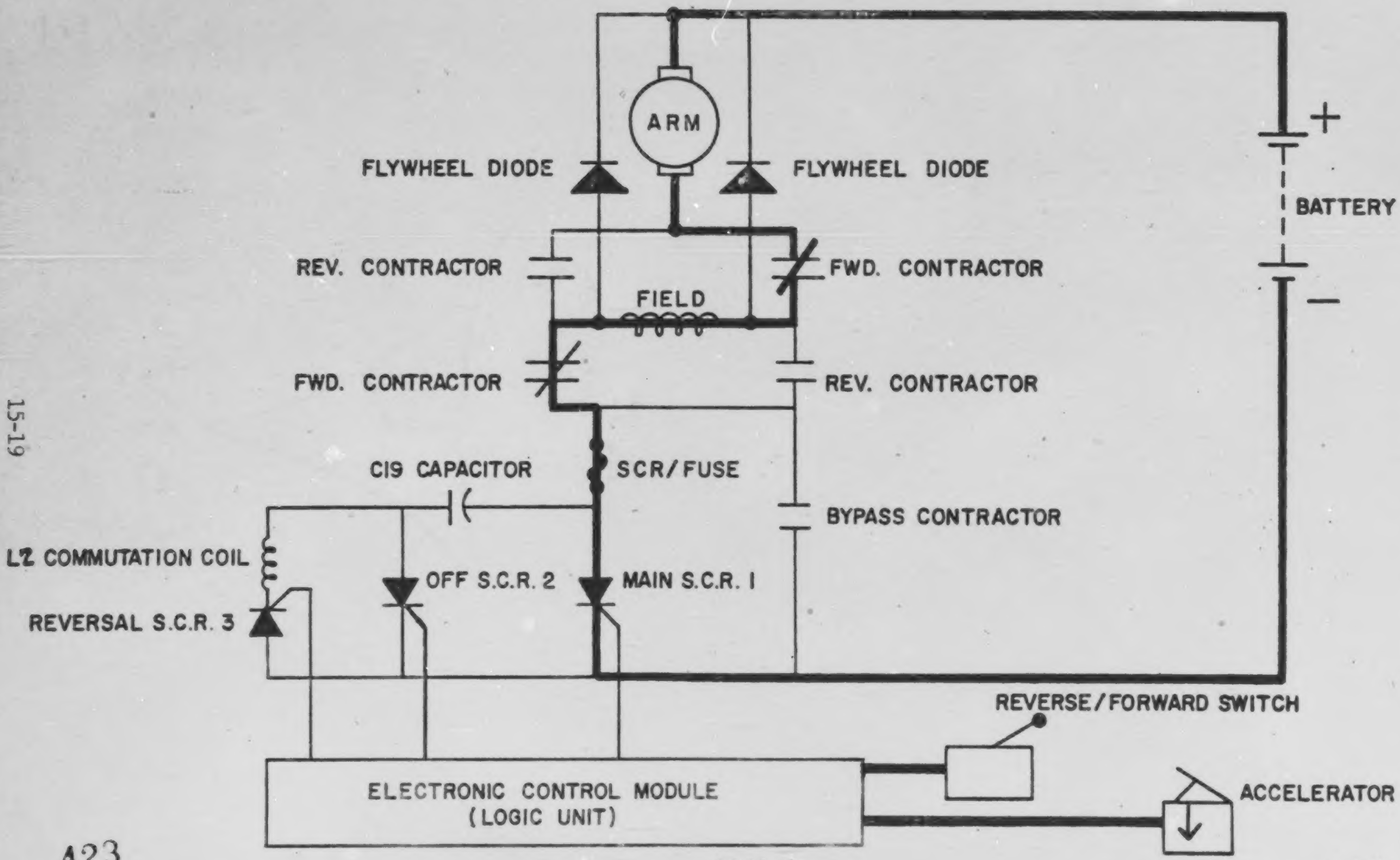
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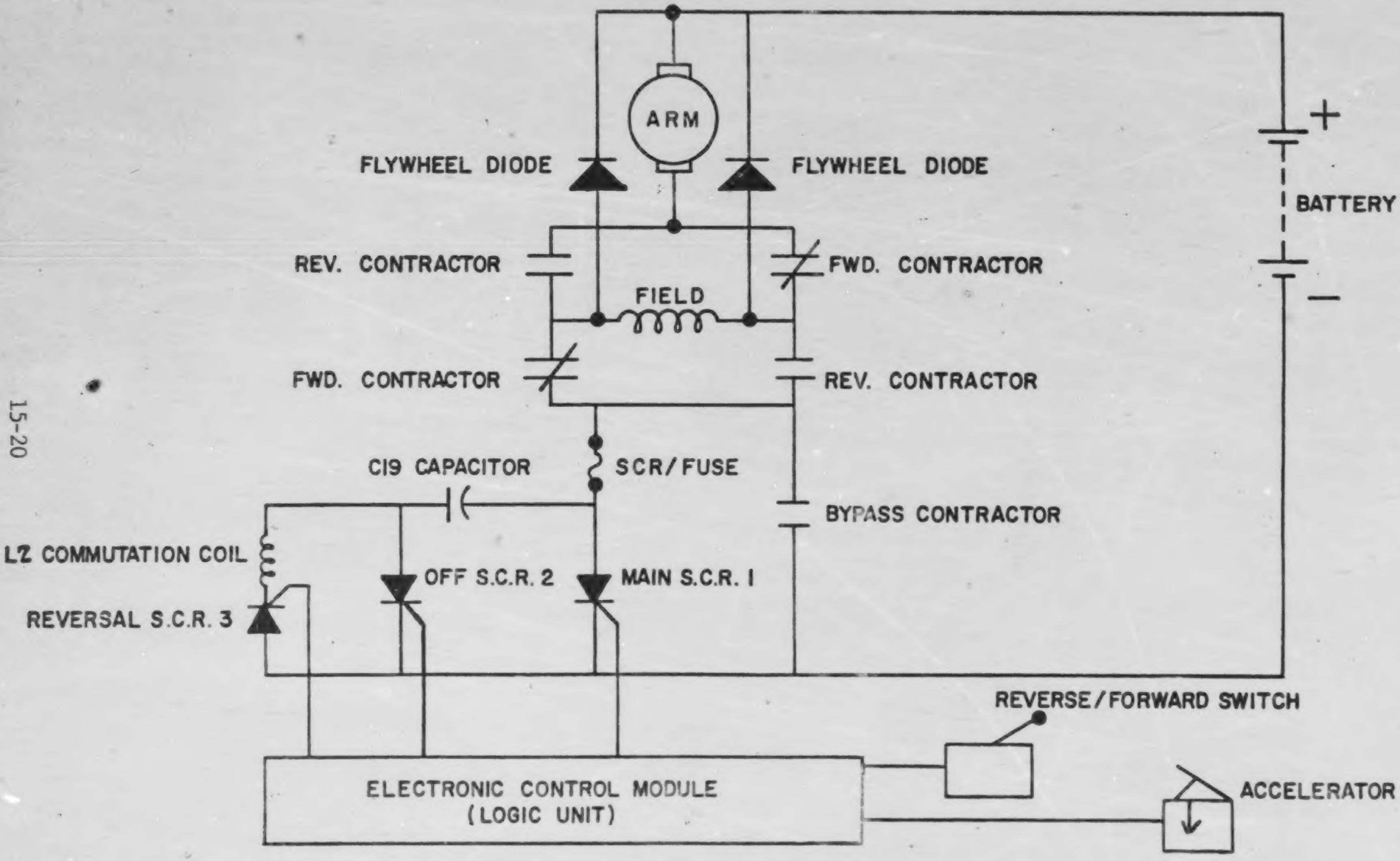
ACCELERATOR

STEP 4

A. SCR #1 CONDUCTING
B. MOTOR STARTS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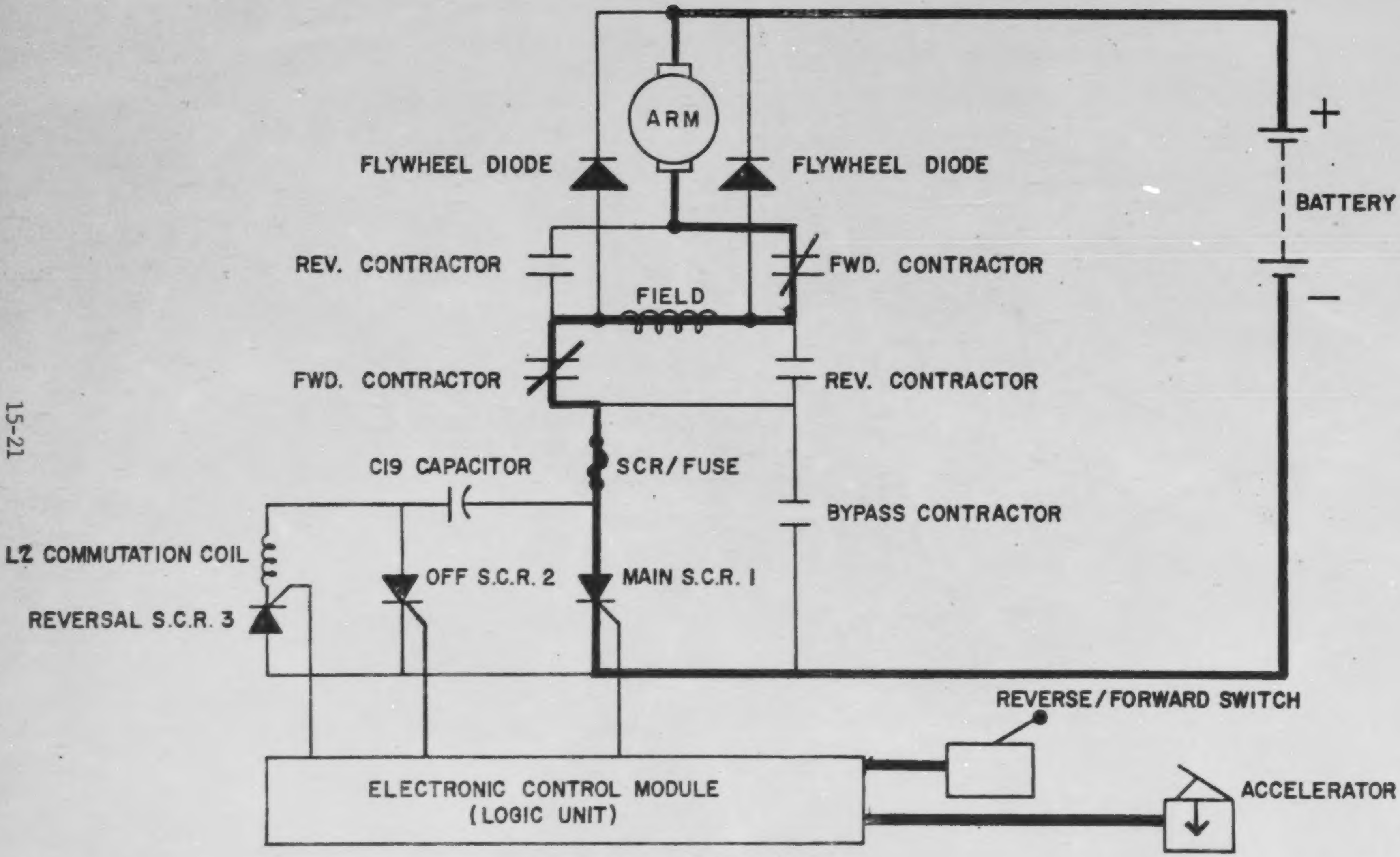
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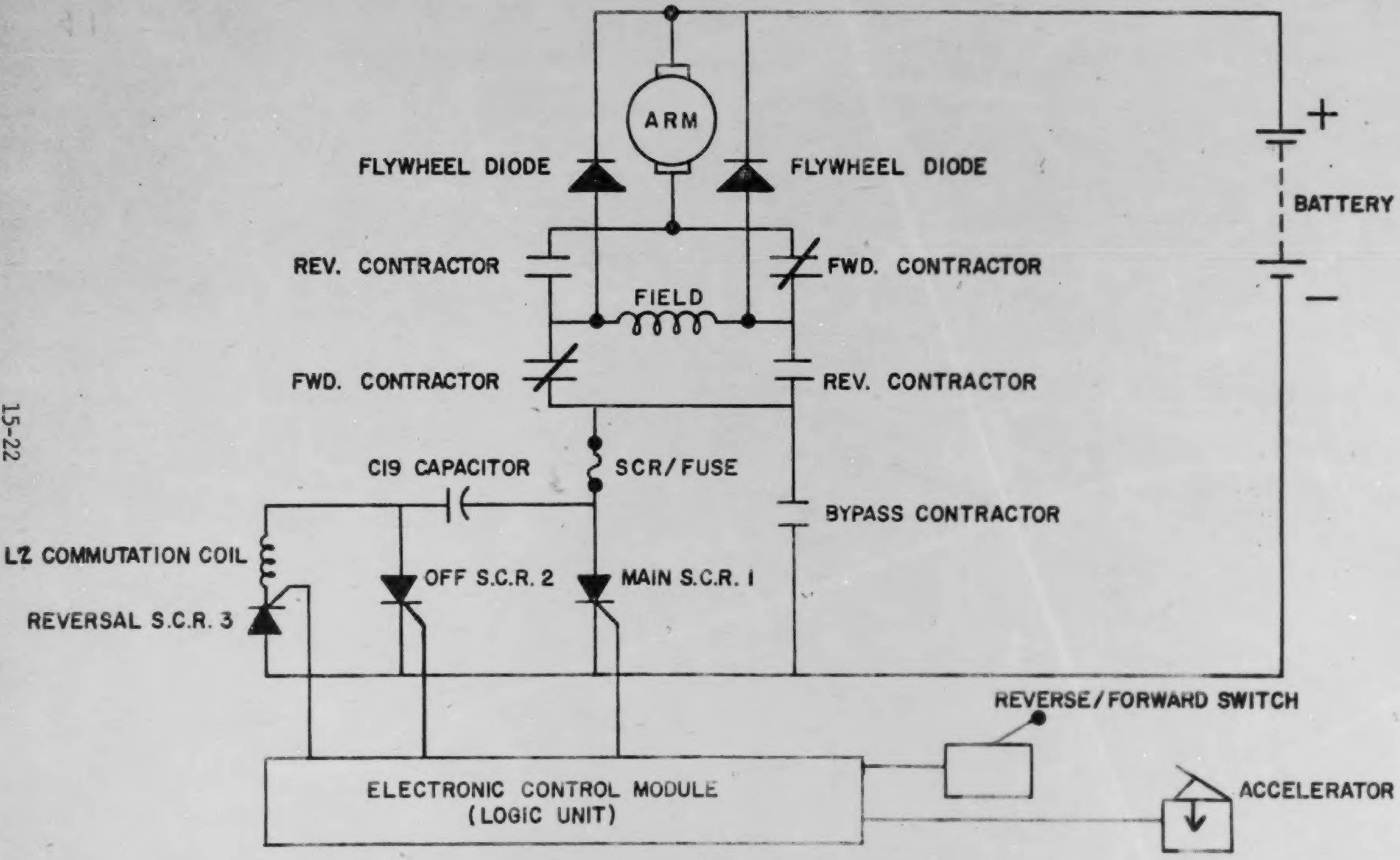
ACCELERATOR

STEP 4C

LOGIC UNIT PULSES SCR #3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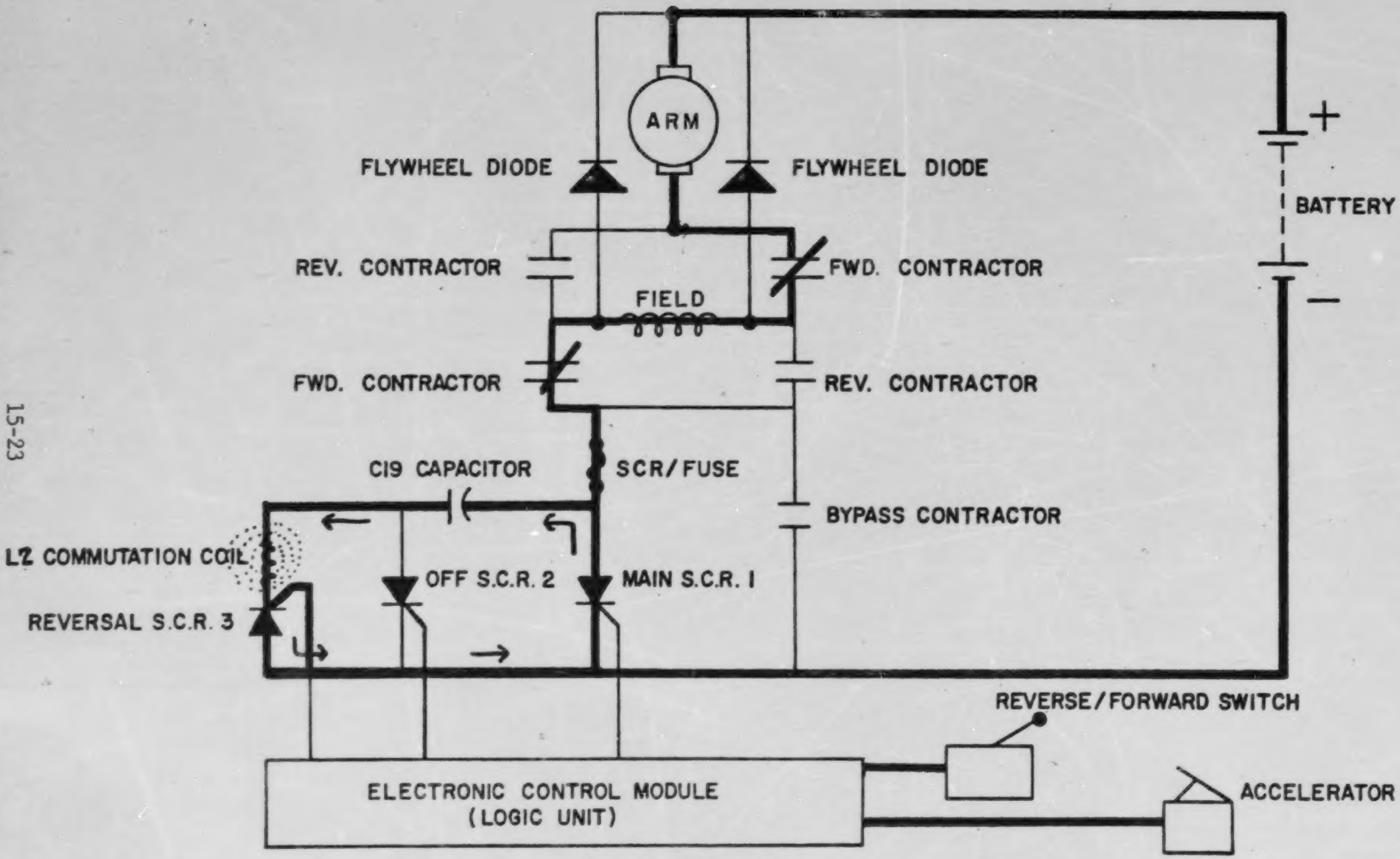
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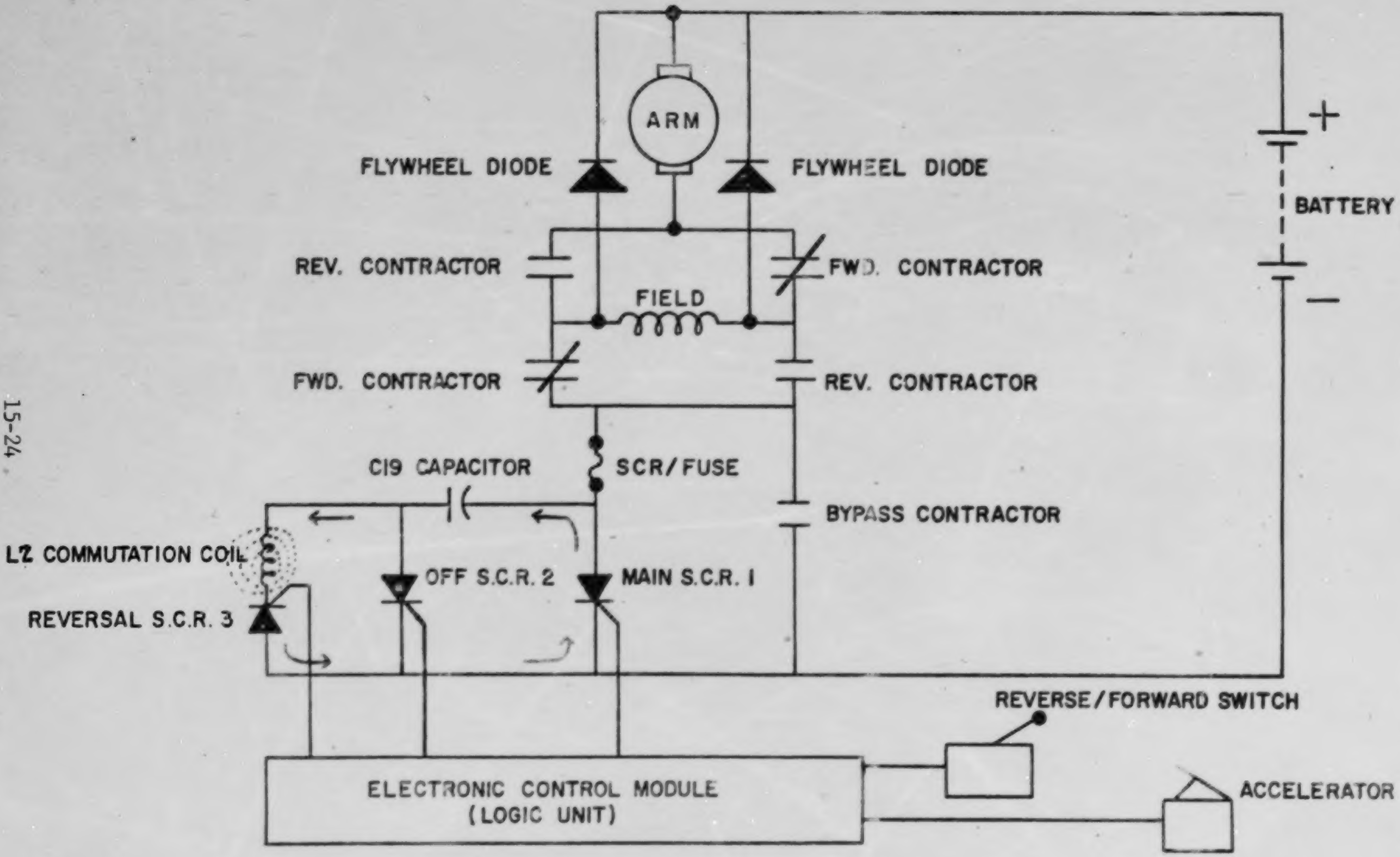
STEP 5

A. CAPACITOR BEGINS DISCHARGING
B. MAGNETIC FIELD PRODUCED BY COIL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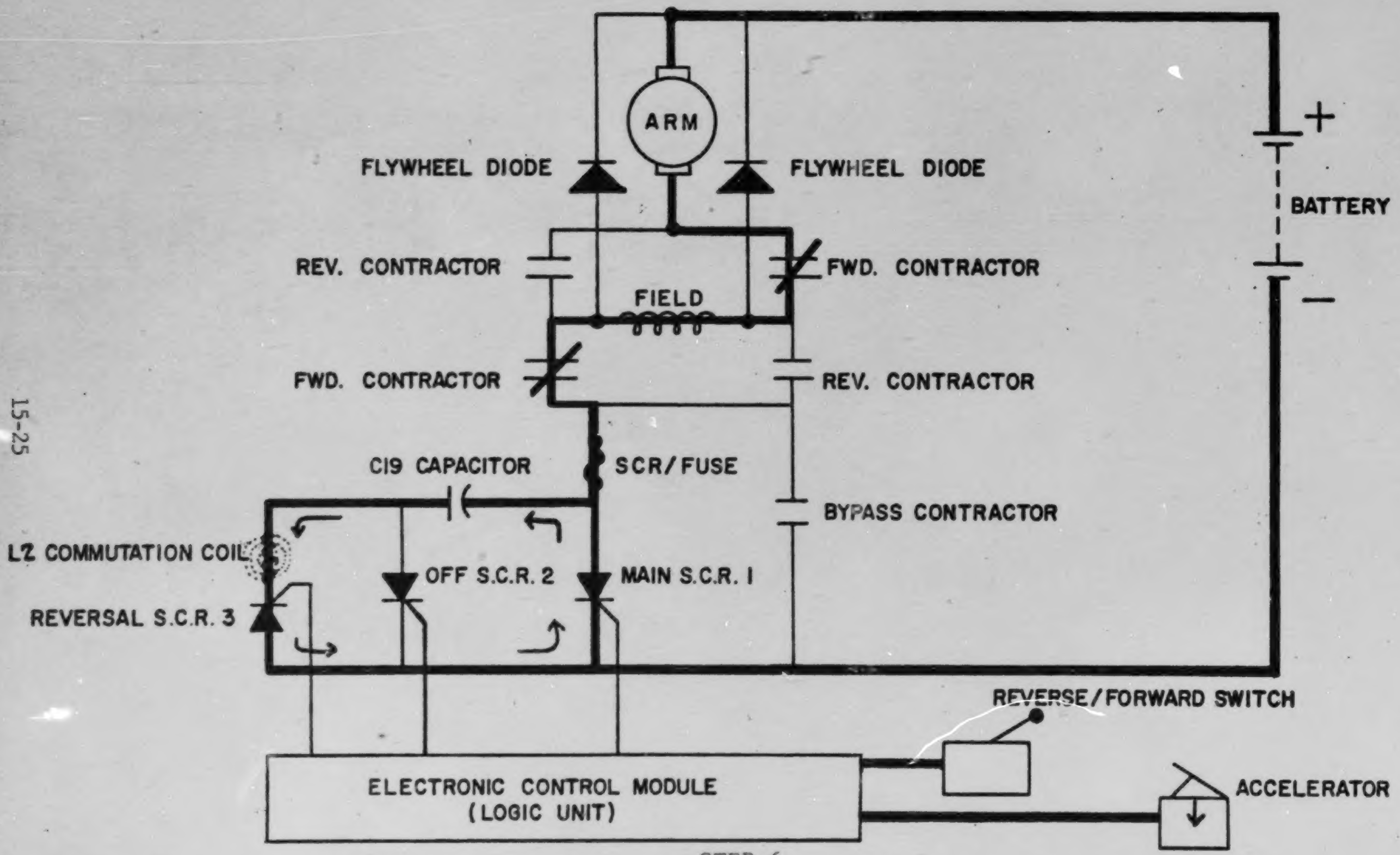
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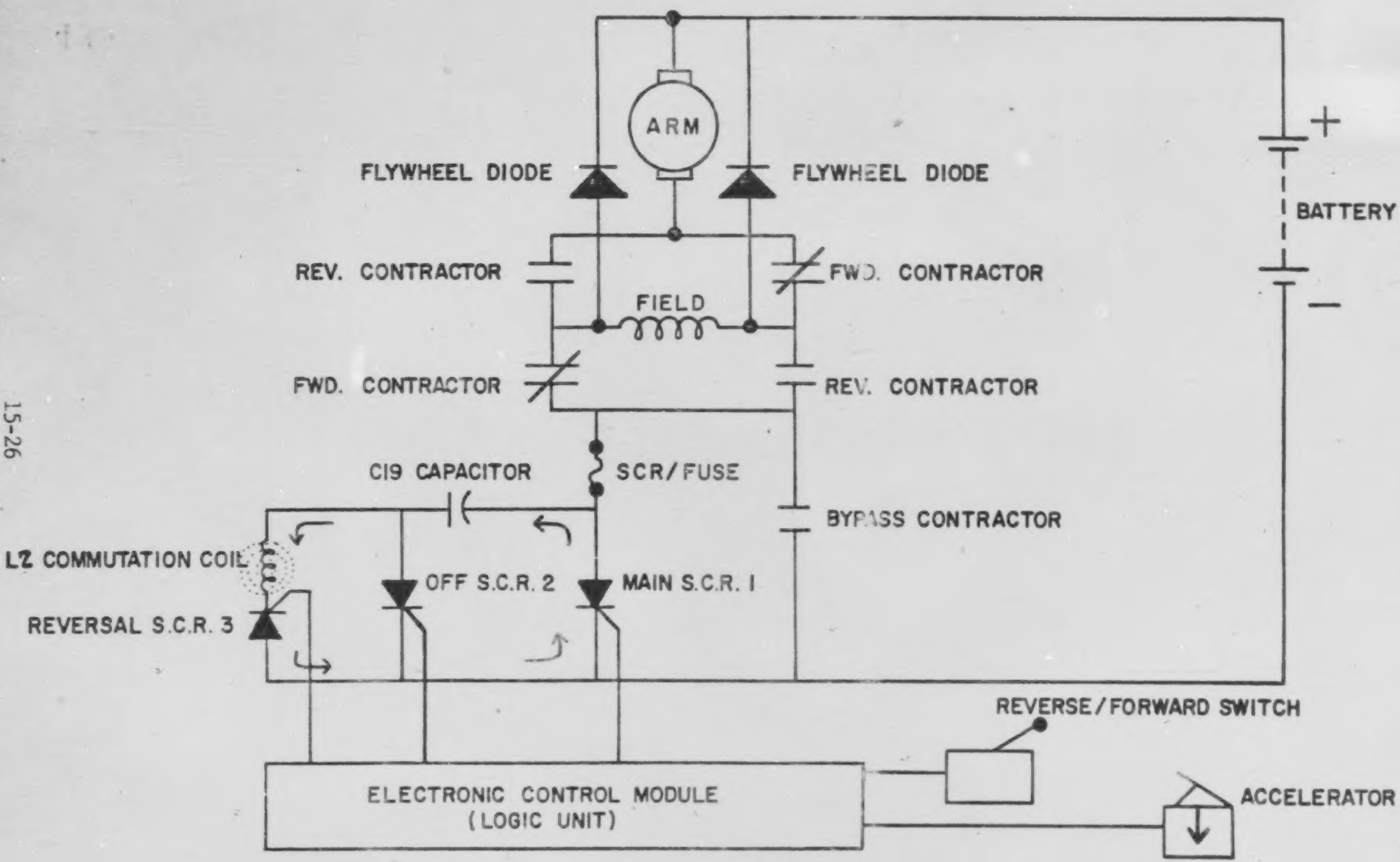
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

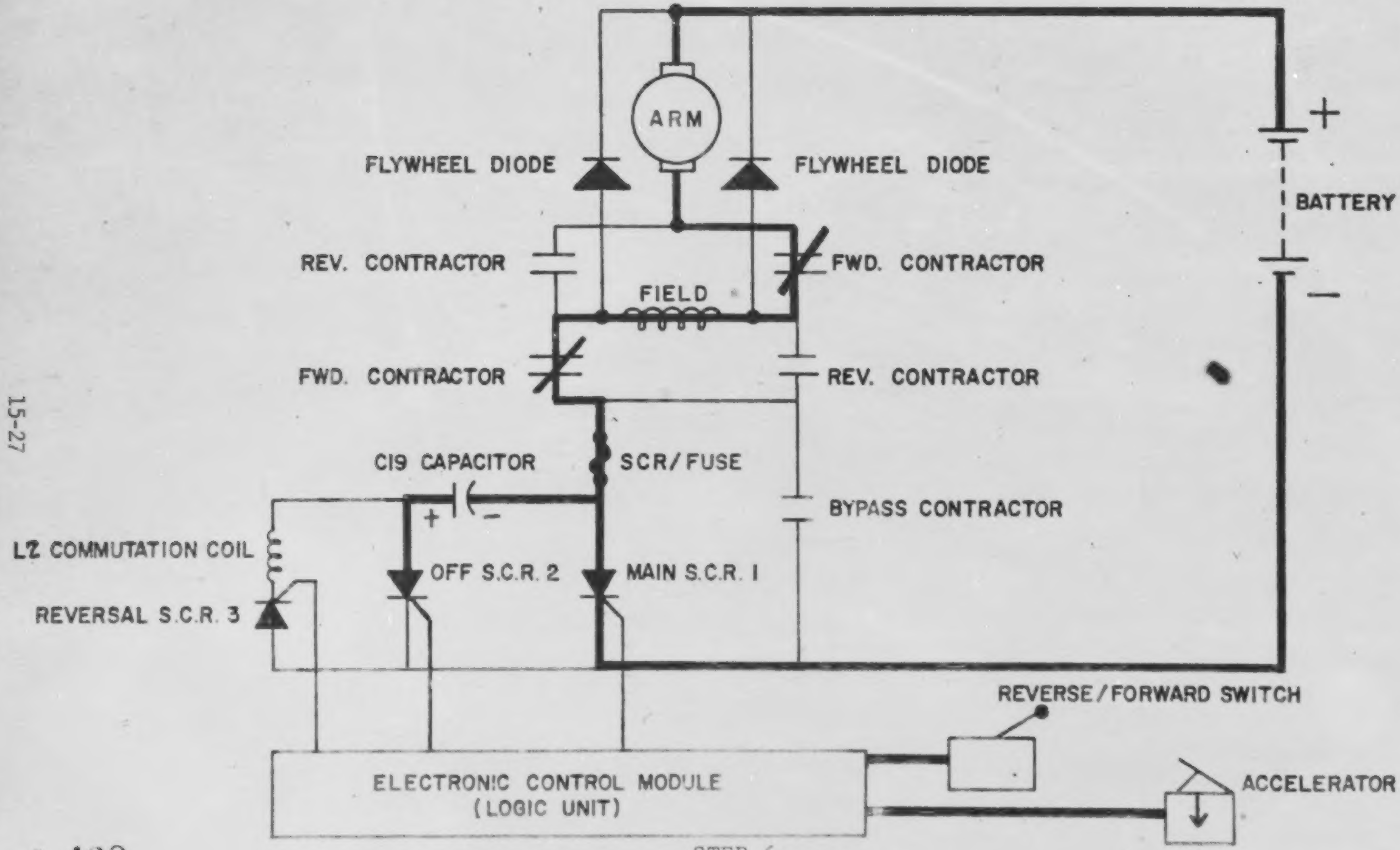
STEP 6

A. SCR #3 PULSE HAS ENDED BUT CONTINUES TO CONDUCT
B. CAPACITOR HAS DISCHARGED
C. MAGNETIC FIELD OF COIL BEGINS TO COLLAPSE,
CHARGING THE CAPACIT[illegible] IN THE OPPOSITE POLARITY

15-26


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
BATTERY
+
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

437


ARM
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REV. CONTRACTOR
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C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
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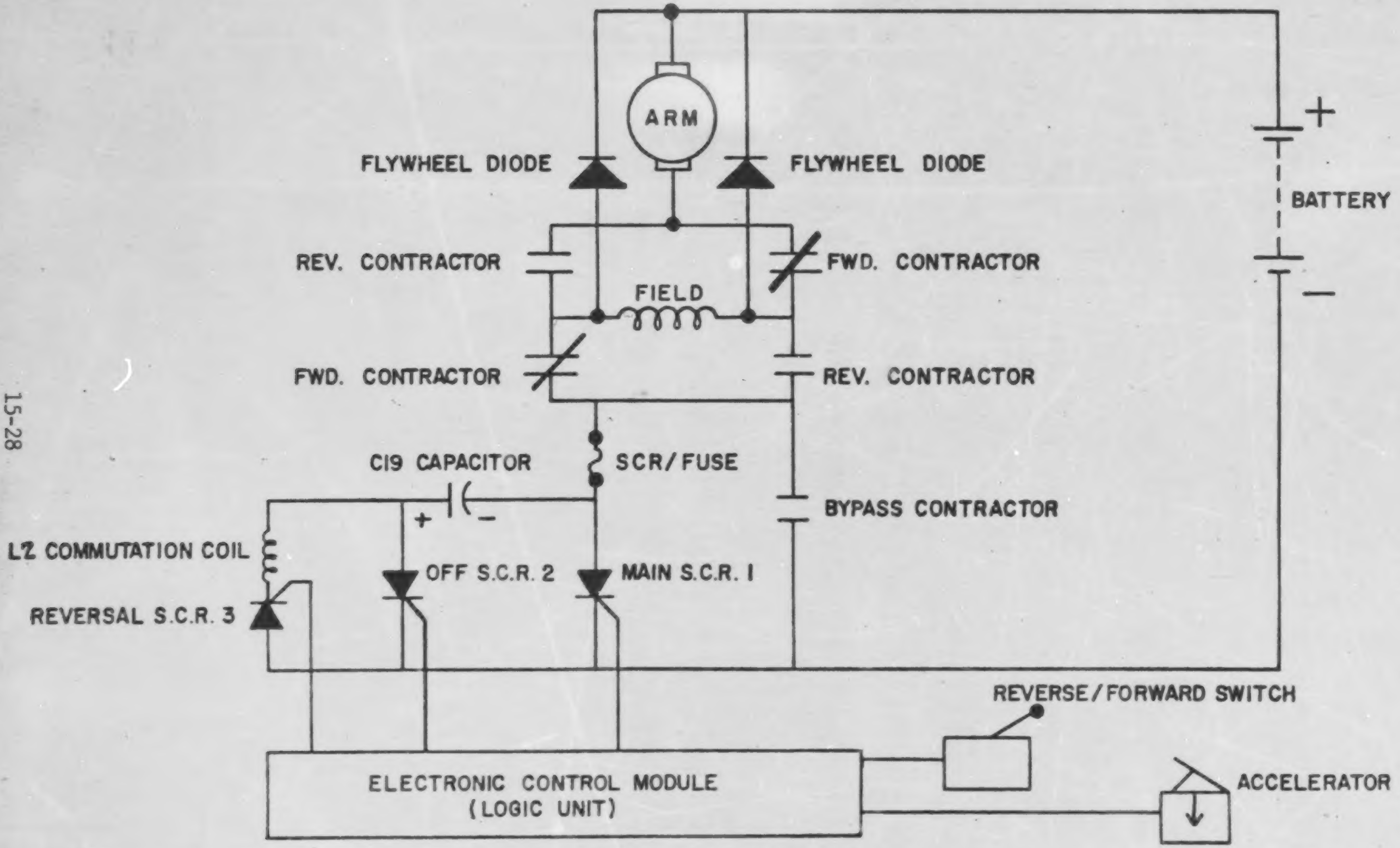
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 6

D. CAPACITOR CHARGED IN OPPOSITE POLARITY
E. INDUCED CURRENT STOPS FLOWING
F. SCR #3 RETURNS TO BLOCKING STATE
G. SCR #1 STILL CONDUCTI[illegible] (MOTOR IS RUNNING)


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
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REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
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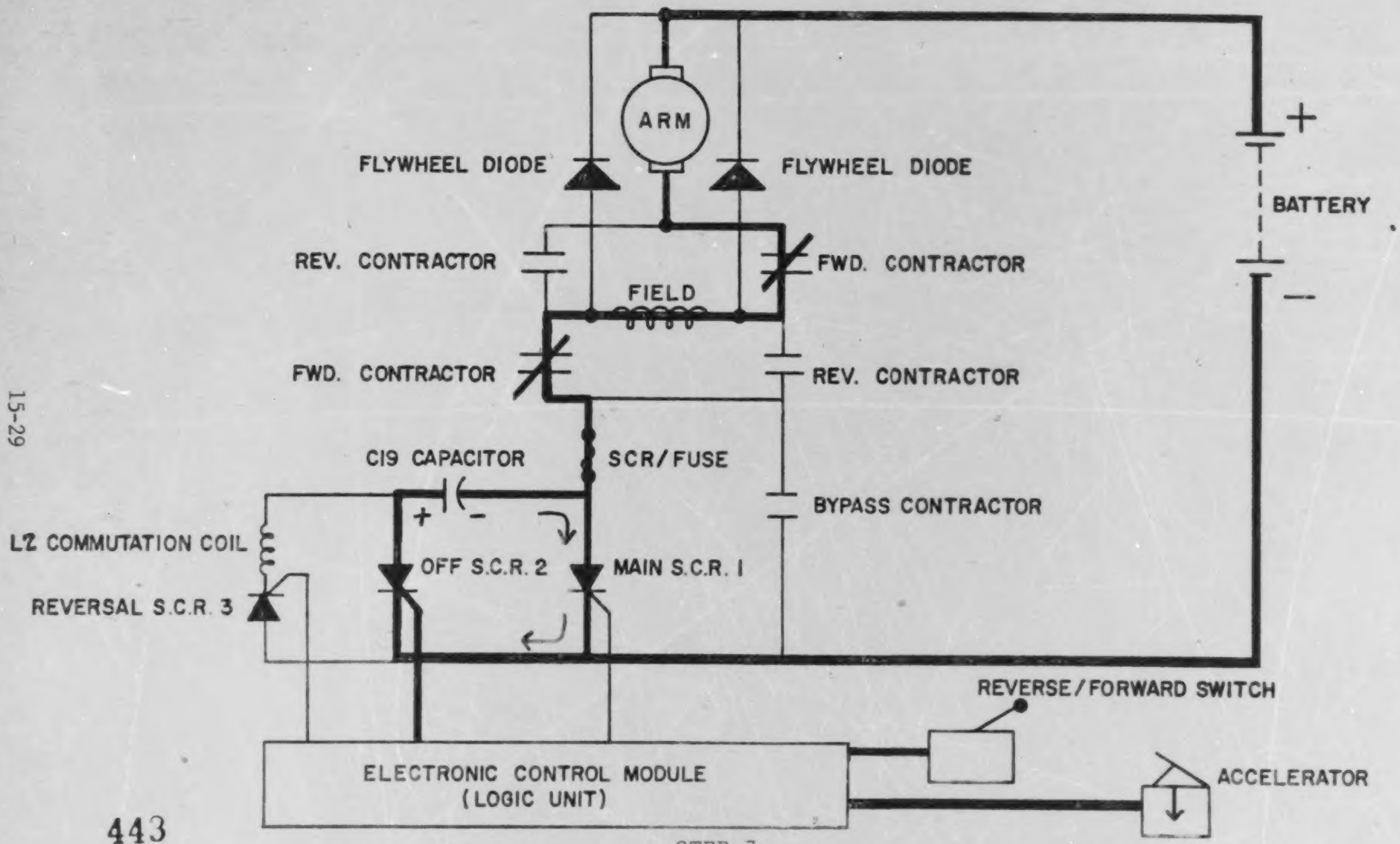
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

15-28

441

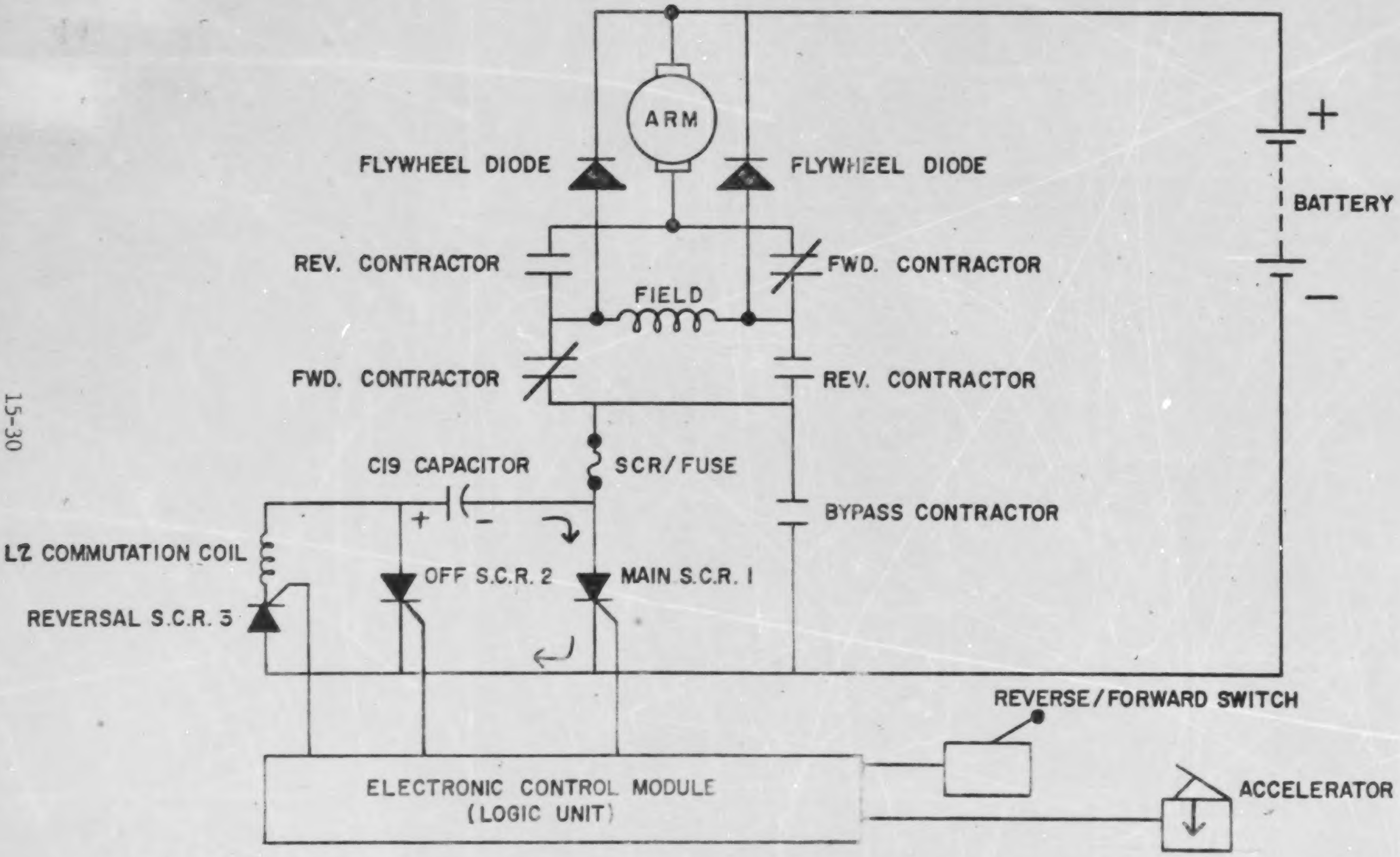
442


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
+
−
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 7

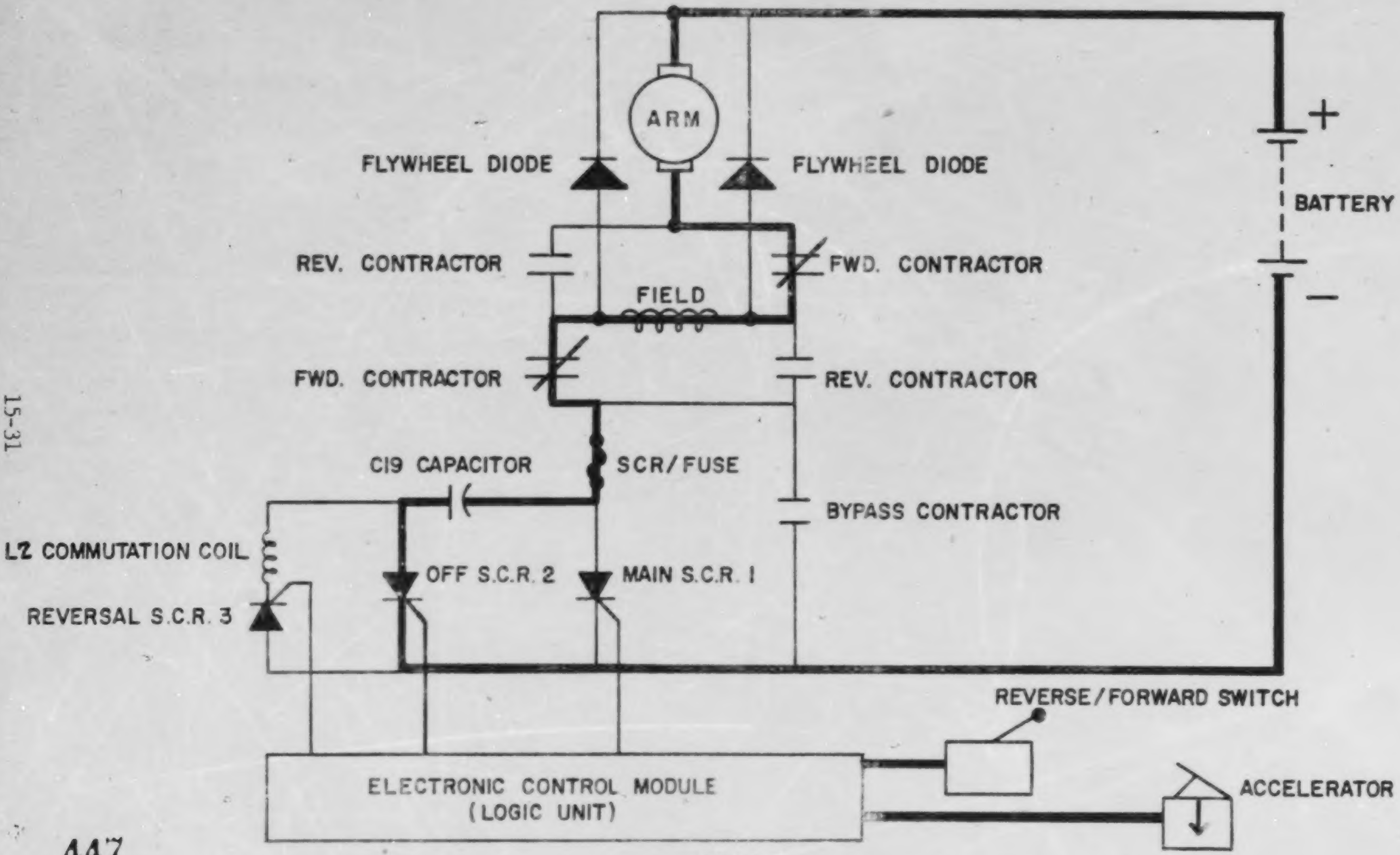
A. CAPACITOR IS CONNECTED TO SCR #1.

B. CAPACITOR CAUSES SCR #1 TO BE REVERSE BIASED AT A HIGHER VOLTAGE THAN THE BATTERY VOLTAGE


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
BATTERY
+
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
+
−
SCR/FUSE
BYPASS CONTRACTOR
LZ COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

15-30

15-31


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
SCR/FUSE
C19 CAPACITOR
BYPASS CONTRACTOR
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

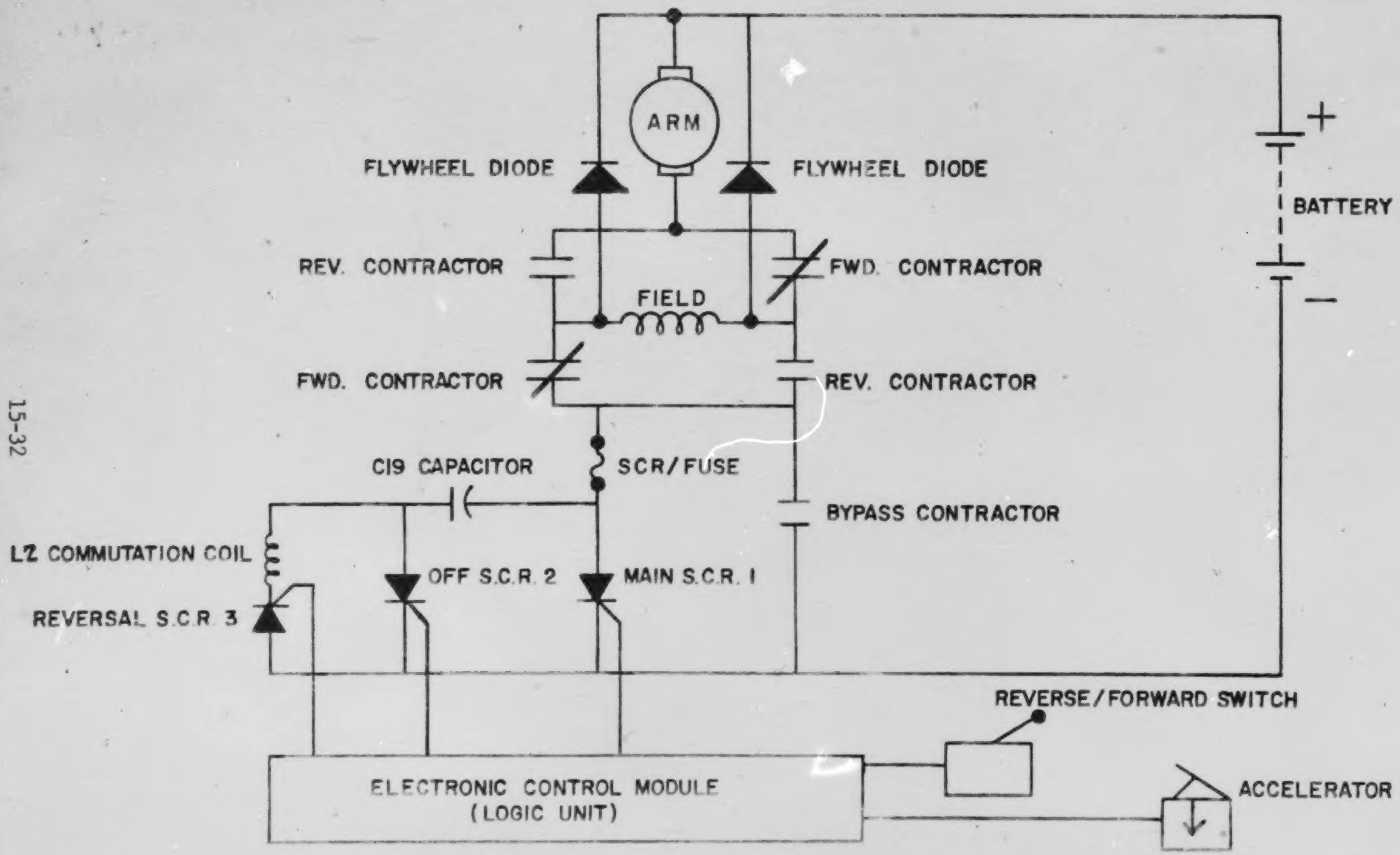
447

448

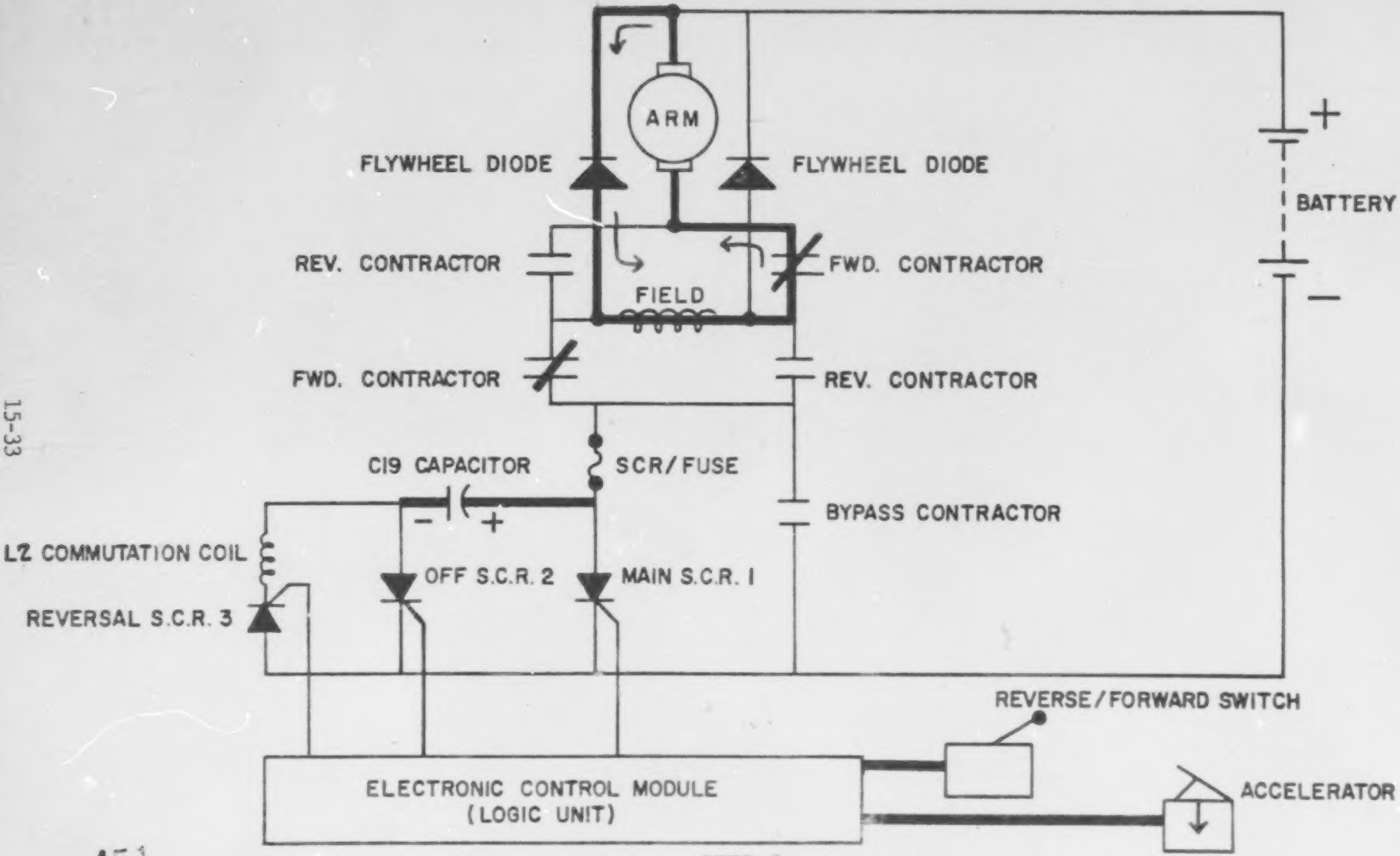
STEP 7

C HIGH REVERSE BIASED VOLTAGE CAUSES SCR #1 TO TURN OFF.
D SCR #2 KEEPS CONDUCTING
E CAPACITOR CHARGES THROUGH THE MOTOR TO ORIGINAL POLARITY.

15-32


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

449


ARM
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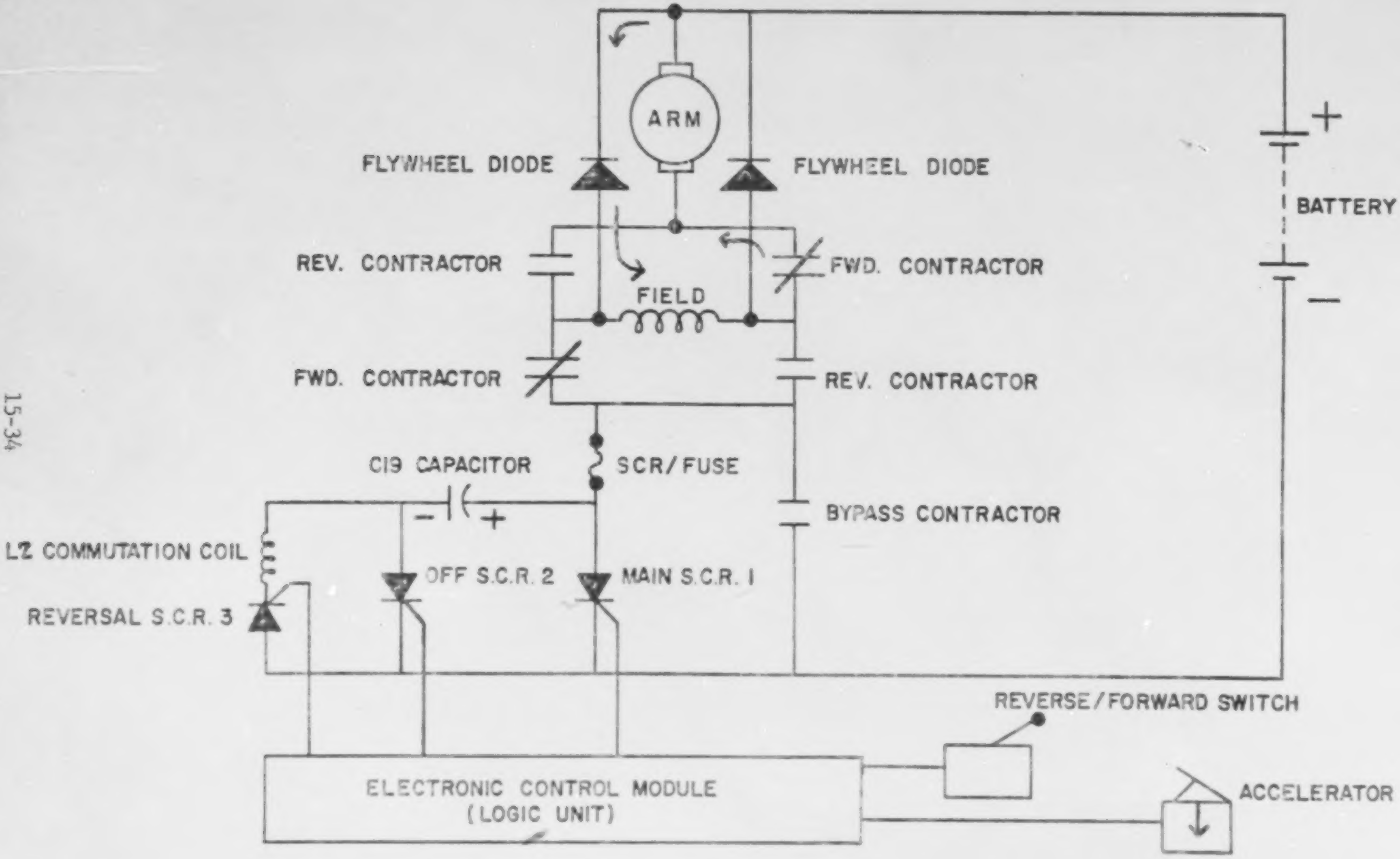
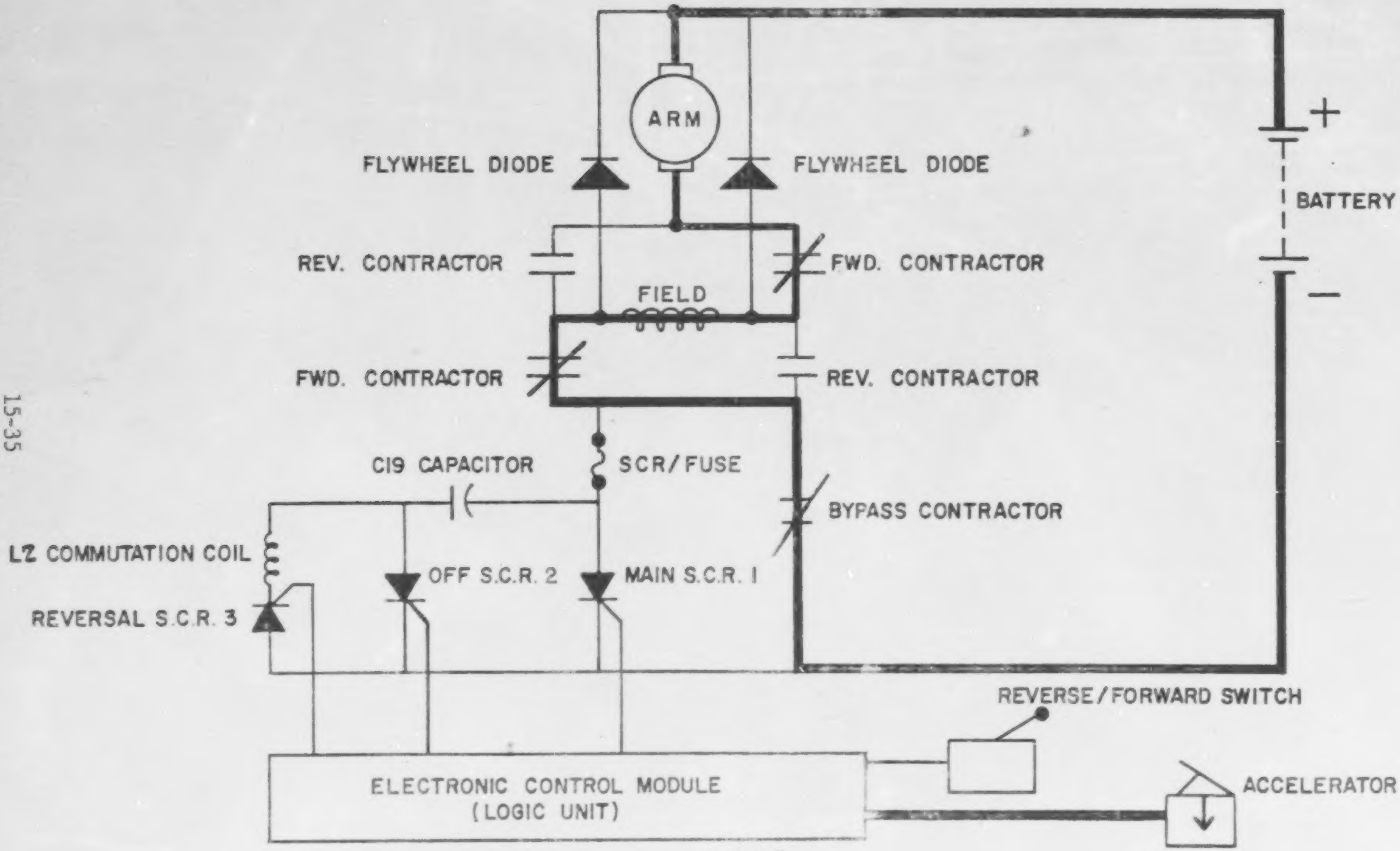
FLYWHEEL DIODE
BATTERY
+
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
−
+
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 8

A. SCR #2 TURNS OFF WHEN CAPACITOR BECOMES CHARGED
B. THE MOTOR IS DISCONNECTED FROM THE BATTERY
C. INDUCED CURRENT CIRCULATES IN THE MOTOR WINDINGS (MOTOR STILL RUNS)

15-34


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
− +
BYPASS CONTRACTOR
LZ COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR


ARM
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FLYWHEEL DIODE
+
BATTERY
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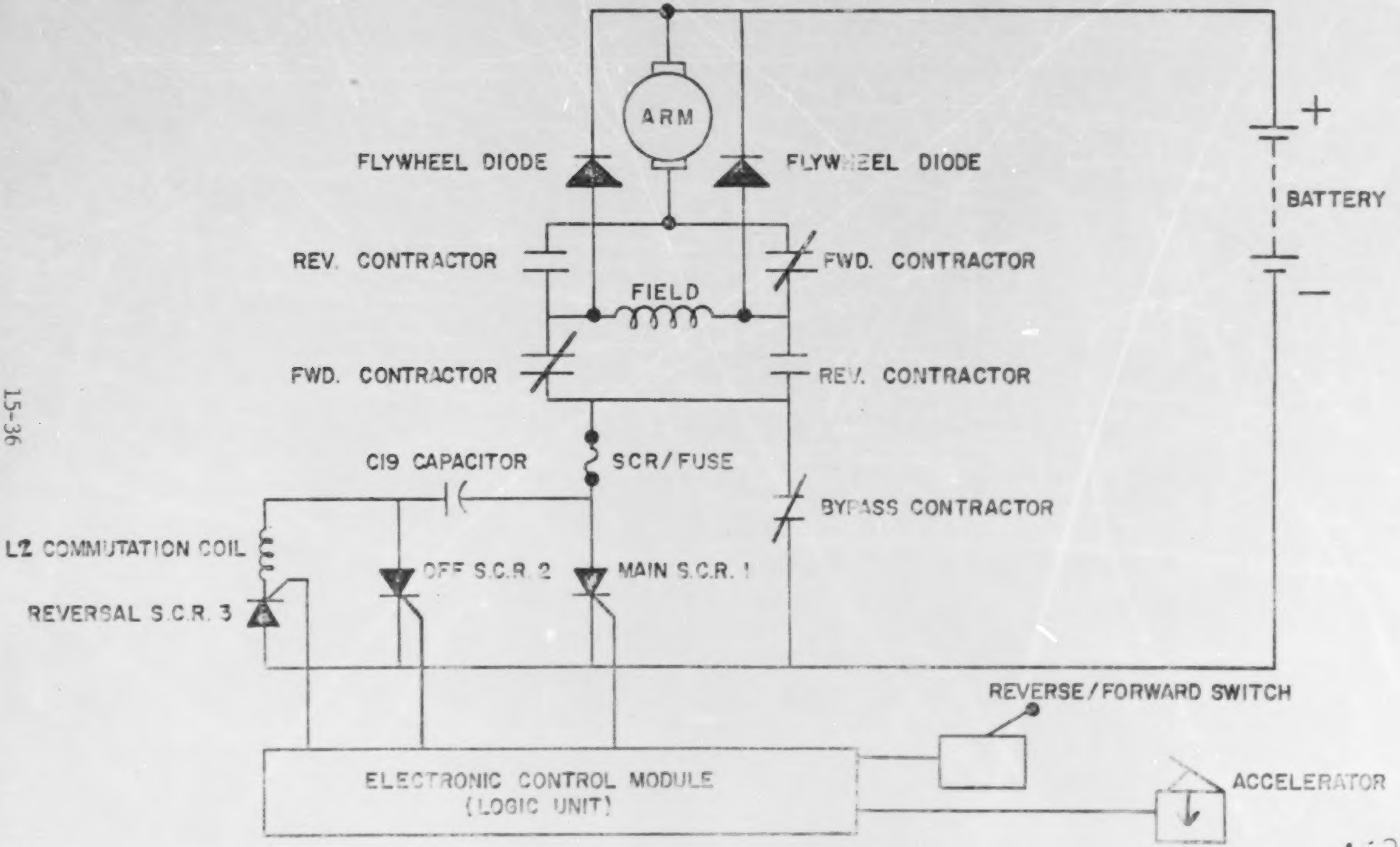
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
SCR/FUSE
BYPASS CONTRACTOR
L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STEP 9

FULL SPEED OPERATION


ARM
FLYWHEEL DIODE
FLYWHEEL DIODE
+
BATTERY
−
REV. CONTRACTOR
FWD. CONTRACTOR
FIELD
FWD. CONTRACTOR
REV. CONTRACTOR
C19 CAPACITOR
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L2 COMMUTATION COIL
OFF S.C.R. 2
MAIN S.C.R. 1
REVERSAL S.C.R. 3
REVERSE/FORWARD SWITCH
ELECTRONIC CONTROL MODULE
(LOGIC UNIT)
ACCELERATOR

STUDENT COMPETENCY SHEET #1

Unit: 16 Belt Starter Components

Competency Statement: Identifies components on belt starter

Performance Objective:

Action: You will identify ten components on the solid state belt starter.

Conditions: Ten belt starter components will be tagged. You will have 20 minutes to identify them. You may not use references.

Standards: All your answers must be correct.

Learning Activities:

1. Get Student Handout #1, "Introduction to the Solid State Control of Three-Phase AC Induction Motors," from the instructor. Read it.
2. Get Student Handout #2, "Belt Starter Component Identification," from the instructor. Read it.
3. Work with another student. Go to the belt starter panel and locate and name the different components. Do the same thing using the arrangement diagram.
4. Tell the instructor when you are ready for the examination. Complete the examination.

STUDENT HANDOUT #1

INTRODUCTION TO THE SOLID STATE CONTROL OF THREE-PHASE AC INDUCTION MOTORS

Unit: 16 Circuit Connections

With the use of solid state power devices has come a new method of motor control. We no longer need to use expensive and complicated motors such as the wound rotor, the delta, wye, and other part-winding motors. The major value of solid state power devices is that a simple squirrel-cage induction motor can be used to get full performance. When squirrel-cage motors are used with conventional controllers, they require low initial inrush current and soft starting. This is not so with the solid state controllers. Solid state starters solve both of these major problems by having a smooth and increasing voltage to the motor. This reduces its inrush current. The motor starts at an ever-increasing (stepless) speed until we get to full speed. With the smooth start of the solid state, never again will belts and gear drives have wear and tear due to jerky starts and speed steps.

SCR Systems

There are two SCR systems. They are the "Three SCR System" and the "Six SCR System." Each system has its advantages and disadvantages. We use one system or the other based on costs and operating conditions.

THE THREE SCR SYSTEM

THE THREE SCR SYSTEM USES THREE SCRS AND THREE DIODES. IN THIS SYSTEM, CURRENT FLOWS THROUGH THE SCRS AND RETURNS THROUGH A DIODE. LOOK AT DIAGRAM 1.

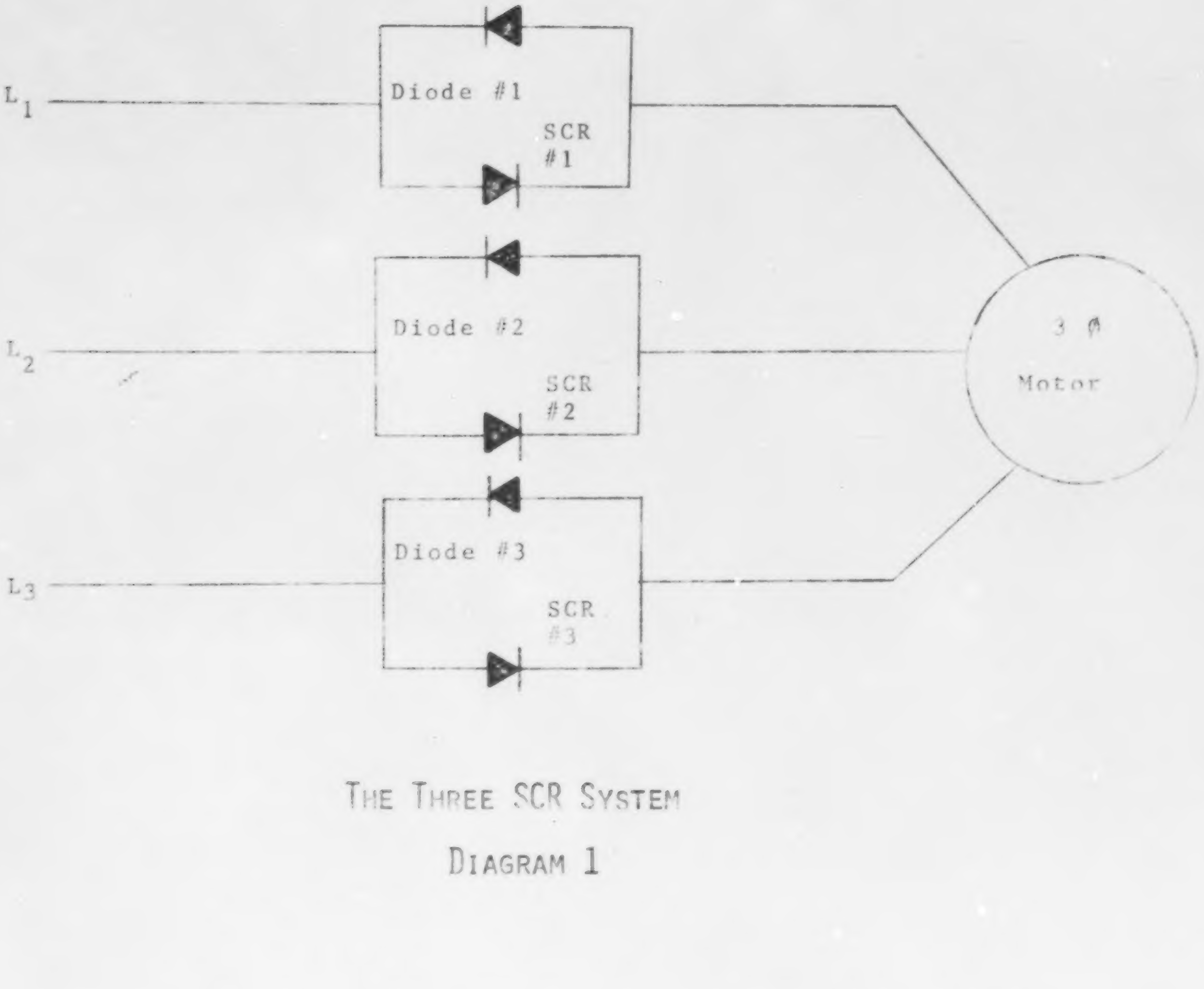
THE MAIN ADVANTAGE OF THIS SYSTEM IS THAT IT COSTS LESS.

SOME OF ITS DISADVANTAGES ARE:

1. STARTING THE MOTOR SEVERAL TIMES WILL CAUSE THE MOTOR TO OVERHEAT.
2. IF THE MOTOR SHOULD BECOME GROUNDED, GROUND CURRENT WILL FLOW THROUGH THE DIODES TO GROUND. THIS WILL BE DIRECT CURRENT AND WILL BURN OUT THE MOTOR.
3. TRIGGERING THE SCR'S IS HOW THE MOTOR IS TURNED ON OR OFF. GROUND CURRENT CAN FLOW THROUGH THE MOTOR EVEN WHEN IT IS OFF.
4. IF ONE OF THE SCR'S BECOMES DEFECTIVE, HIGH SHORT CIRCUIT CURRENT WILL FLOW THROUGH IT AND ONE OF THE DIODES. THIS SHORT CIRCUIT CURRENT IS DC. SINCE IT MUST FLOW THROUGH THE MOTOR WINDING THE MOTOR WILL BURN OUT.

THE SIX SCR SYSTEM

THE SIX SCR SYSTEM USES SIX SCR'S. IT IS MUCH LIKE THE THREE SCR SYSTEM EXCEPT THAT THE DIODES ARE REPLACED WITH SCR'S. THIS SYSTEM OVERCOMES ALL OF THE LIMITATIONS OF THE



L_1
Diode #1
SCR #1
L_2
Diode #2
SCR #2
L_3
Diode #3
SCR #3
3 Ø
Motor

THE THREE SCR SYSTEM

DIAGRAM 1

three SCR system. There is no condition in which uncontrolled DC will flow through the motor. During fault conditions only AC current flows. Look at Diagram 2.

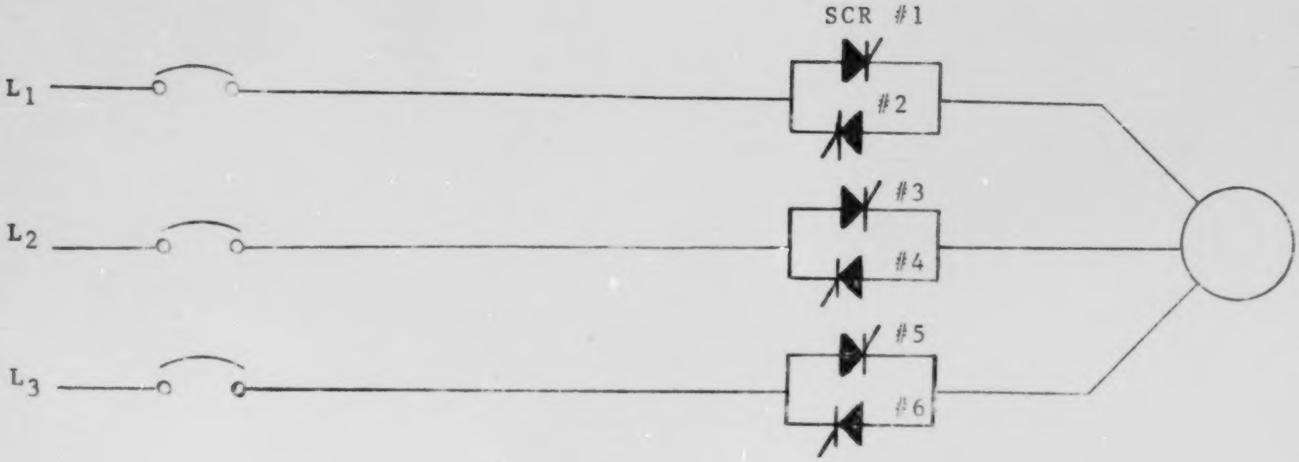
1. If an SCR shorts out there is no return path for current to flow.
2. If an SCR is shorted, and a ground exists in the motor, the ground fault current will be AC, and not DC.
3. If an SCR is shorted, short circuit current will not flow since the other SCR's are blocking.
4. The only way for short circuit current to flow is if two SCR's short out. This hardly ever happens.

CURRENT FLOW IN A THREE-PHASE SYSTEM

The direction of current flow in a three-phase system is continuously changing. Basically, the current flow during any given instant of time will be one of three different situations.

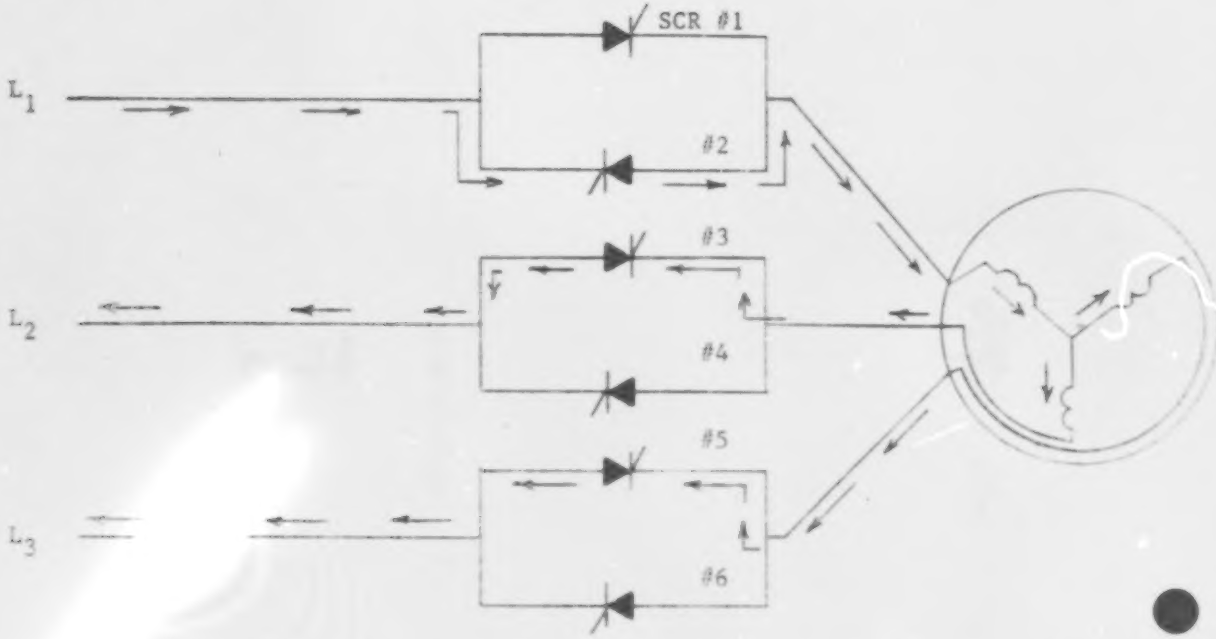
Look at Diagram 3. This is one of the situations. When Line 1 is negative current flows through SCR #2 and the motor windings. It returns through SCR #3 to Line 2, and through SCR #5 to Line 3.

Look at Diagram 4. When Line 2 of the 3-phase system is negative current flows from Line 2, through SCR #4 and through


SCR #1
#2
#3
#4
#5
#6
L_1
L_2
L_3

THE 6-SCR SYSTEM

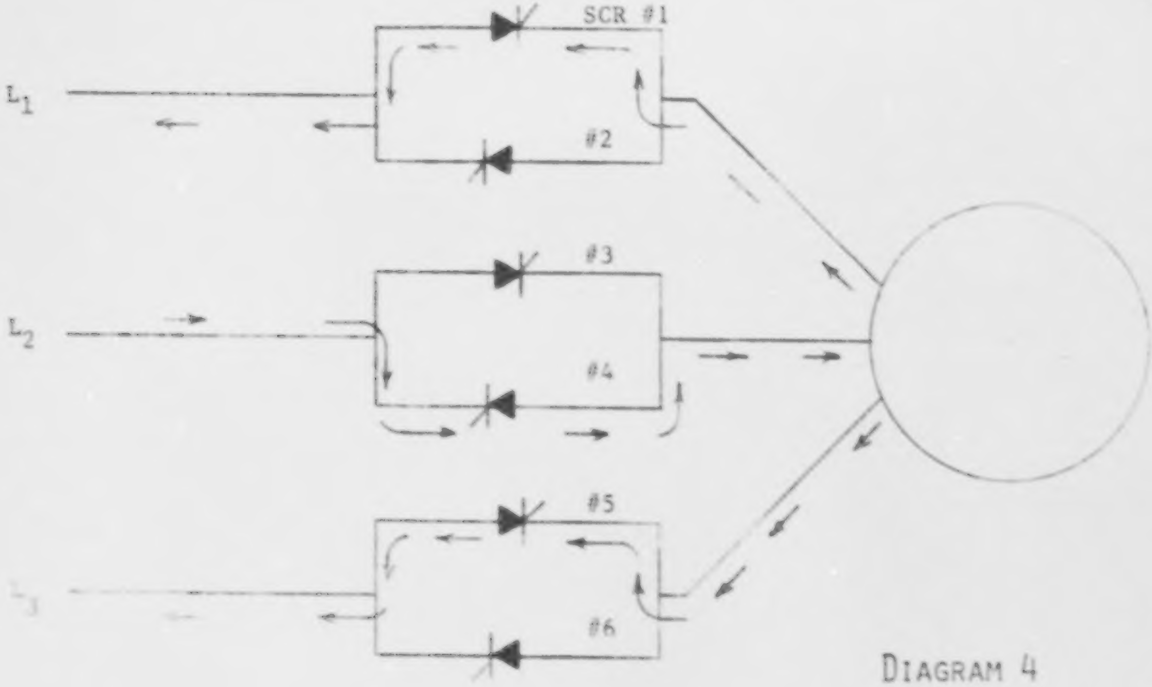
DIAGRAM 2


SCR #1
#2
#3
#4
#5
#6
L1
L2
L3

CURRENT FLOW WHEN L_1 IS NEGATIVE
SCR #S 2, 3, AND 5 CONDUCTING
DIAGRAM 3

the motor. It returns through SCR #1 to Line 1 and through SCR #5 to Line 3.

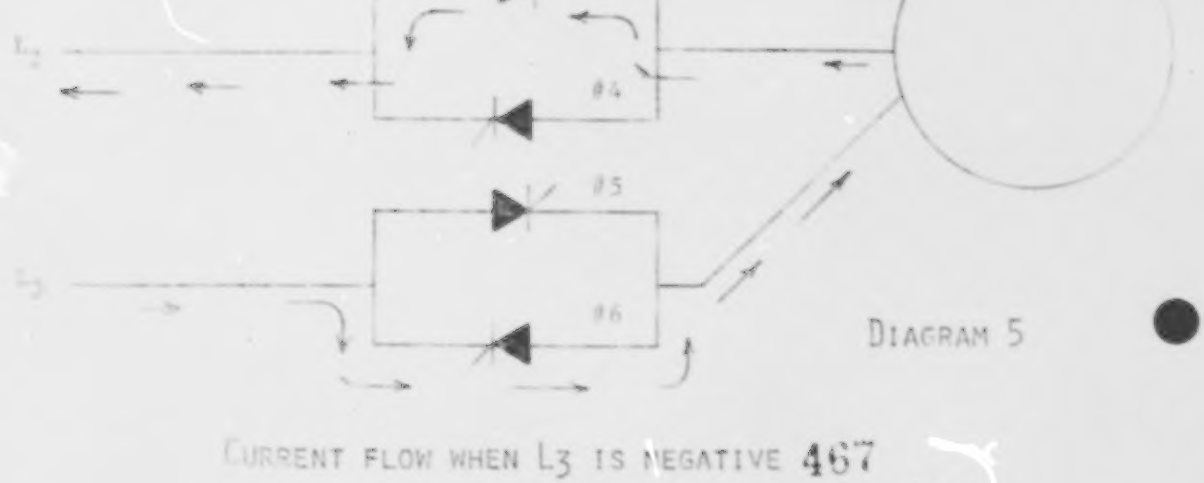
Look at Diagram 5. When Line 3 becomes negative, the current flows from Line 3, through SCR #6 and through the motor windings. It returns through SCR #3 to Line 3, and through SCR #1 to Line 1.



L1
L2
L3
SCR #1
#2
#3
#4
#5
#6

DIAGRAM 4

CURRENT FLOW WHEN L_2 IS NEGATIVE
SCR #s 1, 4, AND 5 CONDUCTING



L1
L2
L3
#1
#2
#3
#4
#5
#6

DIAGRAM 5

CURRENT FLOW WHEN L_3 IS NEGATIVE
SCR #s 1, 3 AND 6 CONDUCTING

STUDENT HANDOUT #2

BELT STARTER COMPONENT IDENTIFICATION

UNIT: 16 BELT STARTER COMPONENTS

NOW THAT WE KNOW ABOUT THE GENERAL OPERATION OF A SOLID STATE THREE-PHASE MOTOR CONTROLLER, LET'S TAKE A LOOK AT THE REAL THING.

AT THE END OF THIS HANDOUT YOU WILL FIND AN ARRANGEMENT OR WIRING DIAGRAM. GET THE DIAGRAM AND TAKE A FEW MOMENTS TO LOOK IT OVER.

THE DIAGRAM SHOWS THE PHYSICAL LOCATION FOR ALL MAJOR COMPONENTS ON THE BELT-STARTER USED IN THIS PROGRAM. IT IS LOCATED IN THE TRAINING AREA. GO FIND THE BELT STARTER PANEL. TAKE THE DIAGRAM AND THE HANDOUT WITH YOU.

LOCATE THE FOLLOWING COMPONENTS ON BOTH THE DIAGRAM AND THE BELT STARTER PANEL.

1. CARD RACK
2. CONTROL TRANSFORMER (CTR)
3. RUN RELAY (R)
4. BELT TAKE-UP RELAY (TU)
5. BELT SLIP TIMER RELAY (BST)
6. CONTROL FUSES (FU-1, FU-2)
7. MAIN CIRCUIT BREAKER (MCB)

8. Varistors (MOV-1, 2, 3, and 4)
9. SCRs (no. 1-6)
10. Control station
11. Current transformer (CT)
12. Resistors and capacitors (between MOV and SCR)

The components on the solid state belt starter will be studied in these three groups: power circuit, logic circuit, and the control circuit.

The Power Circuit

The power circuit has these major components:

1. The main circuit breaker. This is a protective device for the entire panel and motor. It also is the way main power leads are connected to the panel.
2. The SCR's are like contactors that connect the motor to the power source. Also, they are for voltage control. They are connected to form three pairs. There is one pair for each phase wire. Each pair is connected so that motor current can flow in either direction in the main phase wire.
3. A varistor is connected across each pair of SCR's. The varistors will protect the SCR's against high voltages produced by inductance in the motor windings.
4. A resistor and capacitor is connected across each pair

of SCR's. They prevent early firing of the SCR due to inductance.

5. The Current Transformer is connected both in Line 2 of the power circuit and the Card Rack. It monitors the line current and sends a signal to the Card Rack.

The Logic Unit (Card Rack)

The Card Rack is the logic unit or brain of the SCR system. It controls the order and timing of the triggering of the SCR's.

The Card Rack has four (4) printed circuit boards called cards. The cards slide in and out of the Card Rack for easy replacement or maintenance.

1. Firing cards.
   Three of the cards in the Card Rack are firing cards. They are identical and can be interchanged. The card on the left controls the two SCR's in Line 1. The second card controls the SCR's in Line 2. The third card controls the SCR's in Line 3.

2. The Master sensor card
   The master sensor card is located on the right hand side of the Card Rack. When it is energized from the control circuit it signals a firing card to begin firing the

SCR's. It also monitors the motor current through the current transformer. If the motor current is high it keeps the firing cards from triggering the SCR's until later in the cycle. If motor current becomes too high due to an overload the master card will automatically shut the system down. As the motor current decreases the master card permits the firing cards to trigger earlier in the cycle.

The Control Circuit

The control circuit has a control transformer, two fuses, a control switch, three relays, and four external switches. Panel lights are used to show condition during operation.

1. In order to provide automatic protection, a Run "R" Relay is used in the control circuit. Anytime it closes it will connect 120 volts to the input of the card rack. This will start the motor. All protective switches or relays are connected in series with the coil of the "R" relay. This keeps the "R" relay from being energized unless certain conditions are met.

2. On an actual belt line the Sequence Switch would be located in another panel. It keeps the belt starter from operating unless the belt ahead of it is running. Placing the control switch in the "Hand Position" will bypass this switch.

3. The Remote Switch is also located on another panel or a belt line. It is used when operating several belt controls from one location. It is also used for an emergency disconnect.

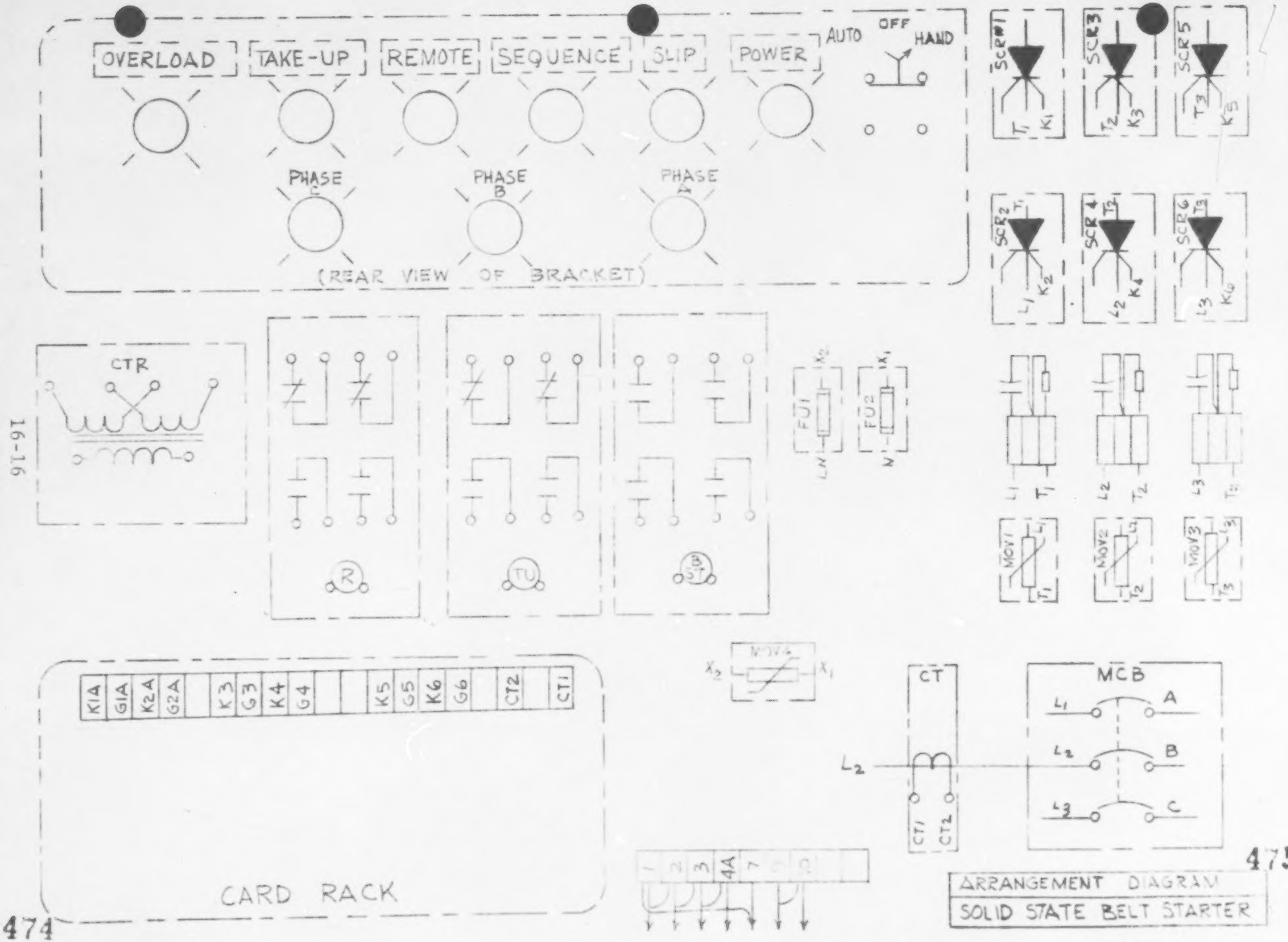
4. Pressure switch and Belt Take-Up Relay.
These two components operate together. The Belt Take-Up Relay is located inside the panel. It controls a belt tension device outside the panel. The Pressure Switch is located outside the panel on the belt tension mechanism. When the belt starter is turned on, the TU relay will automatically cause the belt to tighten up to the proper tension. When it is turned off, the belt automatically loosens. If the belt fails to tighten up, the Pressure Switch keeps the motor from starting.

5. The Speed Slip Switch and the Belt Slip Timer work together to keep the belt from slipping. The Belt Slip Timer bypasses the speed switch when the motor is started. Once the belt begins moving, the Speed Switch closes. The normally closed timing contacts of the BST Relay then open. The Run Relay is now energized through the Speed Switch. If the belt should slip, the Speed Switch would open. This disconnects the Run Relay and stops the motor.

6. Overload protection is provided by the Card Rack. When

THERE IS AN OVERLOAD THE OVERLOAD CONTACTS IN SERIES WITH THE RUN RELAY OPEN. THIS DISCONNECTS THE MOTOR.

IF ANY OF THE EXTERNAL SWITCHES SHOULD OPEN THE RUN RELAY WOULD BE DEENERGIZED. THE MOTOR WOULD STOP. THE PANEL LIGHT FOR THE OPEN SWITCH WOULD BECOME ENERGIZED. THIS WOULD SHOW THE REASON FOR THE SHUT-DOWN.


OVERLOAD
TAKE-UP
REMOTE
SEQUENCE
SLIP
POWER
AUTO
OFF
HAND
PHASE C
PHASE B
PHASE A
(REAR VIEW OF BRACKET)
SCR#1
T1
K1
SCR3
T2
K3
SCR5
T3
K5
SCR2
L1
K2
SCR4
L2
K4
SCR6
L3
K6
CTR
16-16
R
TU
SB
FU1
X2
LN
FU2
X1
N
L1
T1
L2
T2
L3
T3
MOV1
MOV2
MOV3
MOV4
X2
X1
K1A
G1A
K2A
G2A
K3
G3
K4
G4
K5
G5
K6
G6
CT2
CT1
CARD RACK
CT
L2
CT1
CT2
MCB
L1
A
L2
B
L3
C
1
2
3
4A
7
8
9

ARRANGEMENT DIAGRAM
SOLID STATE BELT STARTER

STUDENT EXAMINATION
COMPONENT IDENTIFICATION

UNIT: 16 BELT STARTER COMPONENTS

TAKE THIS EXAMINATION TO THE BELT STARTER PANEL. AT THE PANEL YOU WILL FIND TEN (10) NUMBERED TAGS ATTACHED TO COMPONENTS. WRITE THE NAMES FOR EACH COMPONENT IN THE SPACE BELOW.

TAG NO. NAME OF COMPONENT

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

STUDENT COMPETENCY SHEET #2

UNIT: 17 SCHEMATICS: BELT STARTER

COMPETENCY STATEMENT: TRACES CONTROL AND POWER CIRCUIT CURRENT AND EXPLAINS ITS OPERATION

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL TRACE THE CONTROL AND POWER CIRCUIT OF THE SOLID-STATE BELT STARTER AND EXPLAIN ITS OPERATION.

CONDITIONS: YOU WILL BE GIVEN AN ELECTRICAL PRINT AND 20 MINUTES TIME.

STANDARDS: YOUR TRACING MUST BE CORRECT. THE PANEL MUST WORK THE WAY YOU SAY IT DOES.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "CONTROL CIRCUIT OPERATION." READ THE HANDOUT. USE THE PANEL AS A REFERENCE WHILE YOU READ IT. ANSWER THE STUDY QUESTIONS AT THE END OF THE HANDOUT.
2. GET STUDENT HANDOUT #2, "POWER CIRCUIT OPERATION." READ THE HANDOUT. USE THE BELT STARTER PANEL AS A REFERENCE WHILE YOU READ IT. ANSWER THE STUDY QUESTIONS AT THE END OF THE HANDOUT.
3. OBTAIN TWO SETS OF PRINTS FOR THE BELT STARTER PANEL.
   A. USE A PENCIL TO TRACE THE CONTROL CIRCUIT CURRENT DURING STARTING AND RUNNING.

B. HAVE THE INSTRUCTOR CHECK YOUR DIAGRAMS. CHANGE ANYTHING THAT MAY BE WRONG. EXPLAIN HOW IT WORKS.

4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION.

STUDENT HANDOUT #1

CONTROL CIRCUIT OPERATION

UNIT: 17 SCHEMATICS: BELT STARTER

GET THE CONTROL CIRCUIT DIAGRAM AT THE END OF THIS HANDOUT. LOOK AT IT AS YOU READ THIS.

STARTING THE BELT MOTOR IN THE CENTER "AUTOMATIC" POSITION

1. TURN THE MAIN CIRCUIT BREAKER TO THE "ON" POSITION. THIS ENERGIZES THE BELT STARTER AND THE CONTROL TRANSFORMER.
    A. CONTROL CURRENT FLOW FROM THE CONTROL TRANSFORMER, THROUGH THE OTHER FUSE TO THE OTHER SIDE OF THE CONTROL TRANSFORMER.
    B. CONTROL CURRENT ALSO FLOWS TO THE "HAND-OFF-AUTOMATIC" CONTROL SWITCH.
2. PLACING THE "HAND-OFF-AUTOMATIC" CONTROL SWITCH IN THE "AUTOMATIC" POSITION ALLOWS CONTROL CURRENT TO FLOW THROUGH IT TO THE SEQUENCE SWITCH. ONE OF TWO THINGS CAN HAPPEN HERE.
    A. IF THE HEAD BELT IS NOT RUNNING THE SEQUENCE SWITCH IS "OPEN". CONTROL CURRENT WILL BE BLOCKED. THE BELT WILL NOT START.
    B. IF THE SEQUENCE SWITCH IS "CLOSED" CONTROL CURRENT WILL FLOW THROUGH IT TO THE REMOTE SWITCH.
3. THE REMOTE SWITCH IS AN EXTERNAL SWITCH USED FOR REMOTE

CONTROL OR EMERGENCY STOPPING OF BELT.

A. IF THE REMOTE SWITCH IS "OPEN," CONTROL CURRENT WILL BE BLOCKED. THE BELT WILL NOT START.

B. IF THE REMOTE SWITCH IS "CLOSED," CONTROL CURRENT WILL FLOW THROUGH IT TO BOTH THE PRESSURE SWITCH AND THE TAKE-UP RELAY. THE PRESSURE SWITCH MUST BE OPEN.

4. WHEN THE TAKE-UP RELAY BECOMES ENERGIZED, IT OPERATES AN EXTERNAL DEVICE WHICH TIGHTENS THE BELT. WHEN THE CORRECT BELT TENSION IS REACHED, THE PRESSURE SWITCH "CLOSES."

5. WHEN THE PRESSURE SWITCH "CLOSES" THREE THINGS HAPPEN.

A. CONTROL CIRCUIT POWER IS CONNECTED TO THE SPEED (SLIP) SWITCH. THE SPEED SWITCH IS "OPEN" BECAUSE THE BELT HAS NOT STARTED MOVING. CURRENT FLOW THROUGH IT IS BLOCKED.

B. CONTROL CIRCUIT POWER IS APPLIED TO THE BELT SLIP RELAY CONTACTS. ONE SET OF THESE ARE OPEN. CURRENT CANNOT FLOW THROUGH THEM.

C. CURRENT FLOWS FROM THE PRESSURE SWITCH, THROUGH THE COIL OF THE BELT SLIP TIMER (BST), THROUGH THE FUSE, TO THE CONTROL TRANSFORMER. THIS ENERGIZES THE BST RELAY AND CAUSES ITS CONTACTS TO OPERATE.

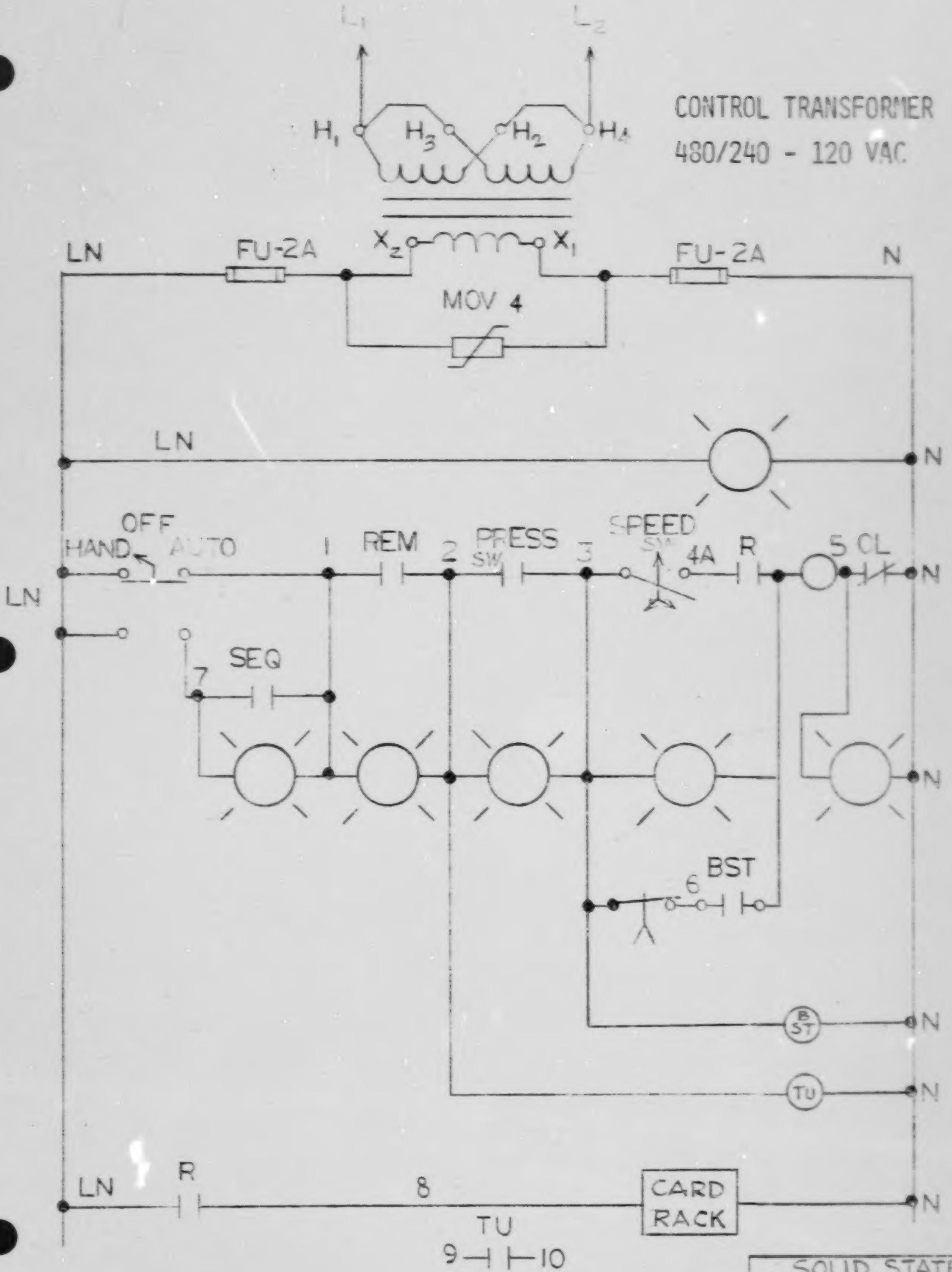
6. WHEN THE BELT SLIP TIMING RELAY (BST) IS ENERGIZED, ITS NORMALLY OPEN CONTACTS CLOSE INSTANTLY. ITS NORMALLY CLOSED (TIME DELAY) CONTACTS BEGIN TO TIME OUT. CONTROL

current now flows from the Pressure Switch through the time delay contacts, the instantaneous contacts of the BST Relay, through the Run (R) relay, through the Overload contacts, and through the control fuse, to the Control Transformer.

7. When control current energizes the Run Relay, it operates and closes the "R" contacts.
   A. When the "R" contacts close, the Card Rack is energized, and the Belt motor starts. The BST time delay contacts are still closed.
   B. As the belt speed increases, the Speed Switch attached to it closes.
8. When the Speed Switch closes, control current flows through it, through the set of "R" contacts, to the R coil, through the overload contacts, and through the control fuse to the Control Transformer.
9. The BST Time Delay contacts open. The "R" relay reamins energized through the Slip Switch and "R" maintaining contacts.
10. If the Control Switch, the Sequence Switch, the Remote Switch, Pressure Switch, or Speed Switch is opened momentarily, the "R" relay will become deenergized. The belt starter will shut down the motor. A pilot light connected across each switch will show the operator which switch opened.

If the Speed Switch causes the shut down the Control

SWITCH MUST BE TURNED "OFF," AND THEN BACK "ON" TO RESTART THE MOTOR. THIS ALLOWS THE BST RELAY TO RESET.



L1
L2
H1
H3
H2
H4
CONTROL TRANSFORMER
480/240 - 120 VAC
LN
FU-2A
X2
X1
FU-2A
N
MOV 4
LN
N
OFF
HAND
AUTO
1
REM
2
PRESS
SW
3
SPEED
SW
4A
R
5
CL
N
LN
SEQ
7
N
6
BST
BST
N
TU
N
LN
R
8
CARD RACK
N
TU
9
10

SOLID STATE
BELT STARTER
CONTROL CKT.

STUDY QUESTIONS

Unit: 17 Schematics: Belt Starter

1. The Solid State AC Belt Starter used in the training laboratory has the 3-SCR system or 6-SCR system.
2. The control transformer on the Solid State AC Belt Starter is protected by
   - a. Fuses in the primary winding
   - b. Fuses in the secondary winding
   - c. Both of the above
   - d. It does not use fuses, but has a circuit breaker instead.
3. The Belt Slip Timer has a 20-second delay. Is this delay activated when it is energized, or when it is deenergized?

4. What is the secondary voltage or the control voltage of the Solid State AC Belt Starter?

5. The belt motor is running. It is at full speed. What control contacts and switches are keeping the Run Relay energized?

6. List four functions provided by this controller.
   - a.
   - b.
   - c.
   - d.

7. Which relay becomes energized first? Second? Last?
   A. Run Relay
   B. Belt Slip Timer Relay
   C. Take-Up Relay

8. What happens if the Control Switch is placed in the "Hand" position?

9. On a belt line operation which of the following switches would not be on the belt starter panel?
   A. Pressure switch
   B. Sequence switch
   C. Remote switch
   D. Speed switch
   E. All of the above

STUDENT HANDOUT #2

POWER CIRCUIT OPERATION

UNIT: 17 SCHEMATICS: BELT STARTER

GET THE POWER CIRCUIT DIAGRAM AT THE END OF THIS HANDOUT. LOOK AT IT AS YOU READ THIS.

THIS DIAGRAM IS LIKE THOSE THAT YOU USED WHEN YOU STUDIED THE THREE SCR SYSTEM AND THE SIX SCR SYSTEM. THE ONLY DIFFERENCES ARE THAT THE CARD RACK (LOGIC UNIT), THE CURRENT TRANSFORMER (CT), AND PHASE INDICATING LIGHTS ARE SHOWN. A VARISTOR, CAPACITOR, AND SMALL RESISTOR IS CONNECTED ACROSS EACH SET OF SCR'S TO PROTECT THEM AGAINST HIGH INDUCED VOLTAGES, AND PREMATURE FIRING.

OPERATION

1. THE CONTROL SWITCH IS TURNED "ON," 120 VOLTS AC IS APPLIED TO THE INPUT TERMINALS OF THE CARD RACK.
2. THE MASTER SENSOR CARD IN THE CARD RACK SIGNALS THE FIRING CARDS TO "FIRE".
3. THE FIRING CARDS RECEIVE A SIGNAL FROM THE AUXILLIARY CATHODE LEAD TELLING THEM WHEN THE CATHODE OF THE SCR IS NEGATIVE. THIS MEANS IT IS READY TO FIRE.
4. SCR'S 2, 3, AND 5 HAVE A NEGATIVE CATHODE WHEN LINE #1 IS NEGATIVE. THE FIRING CARDS SEND A POSITIVE PULSE TO

each of these SCR's. They fire into conduction and the motor starts.

5. The Master Sensor Card receives a signal from the Current Transformer that current flow is too high.

6. The Master Sensor Card signals the Firing Cards to delay firing of the SCR's until later in each cycle. This reduces motor current.

7. Line 2 becomes negative. The cathodes of SCR #4 and SCR #1 become negative. They fire. This permits current to flow through them. SCR #5 is still in conduction and does not need to be triggered.

8. Line 3 becomes negative. This causes SCR's #6 and #3 to have a negative cathode. Number 1 is still in conduction and does not need to be triggered.

9. The Firing Cards trigger SCR #6 and SCR #3. This permits current to flow through them.

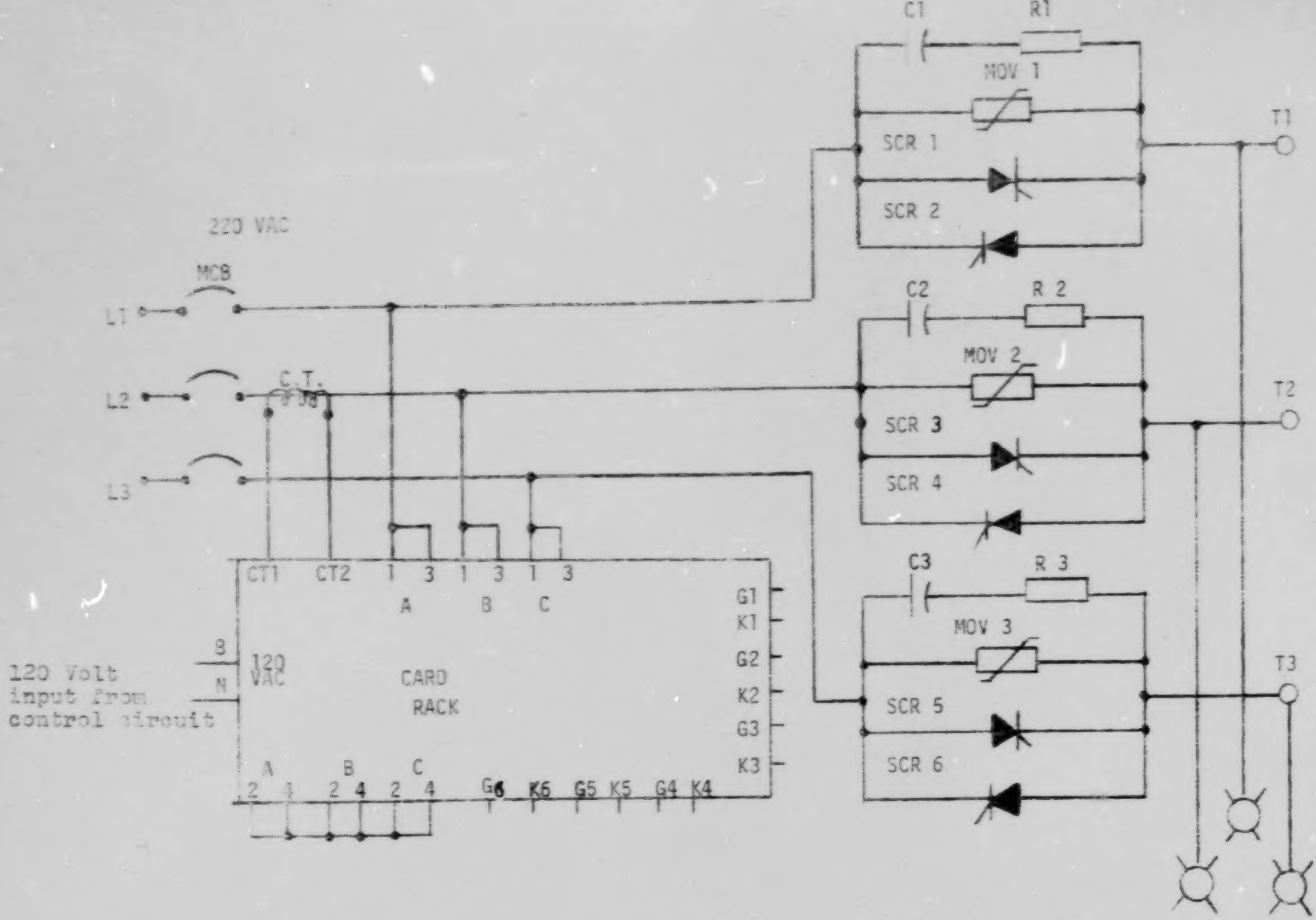
10. Steps 1-9 continue as long as input power is applied to the Card Rack. The motor speeds up and motor current begins to decrease.

11. The Master Sensor Card rec[illegible] signal from the Current Transformer that the current is decreasing.

12. The Master Sensor Card tells the firing cards to begin firing earlier in each cycle. This applies more voltage to the motor and the motor speeds up. Line current decreases again. The Firing Cards continue to fire the SCR's earlier and earlier in each cycle until full voltage is connected to the motor.

13. Should an overcurrent occur due to an overload the Master

Sensor Card tells the overload contacts to open. This disconnects the Card Rack and causes the system to shut down.


C1
R1
MOV 1
SCR 1
SCR 2
T1
220 VAC
MCB
L1
L2
L3
C.T.
C2
R 2
MOV 2
T2
SCR 3
SCR 4
C3
R 3
MOV 3
T3
SCR 5
SCR 6
CT1
CT2
1 3 1 3 1 3
A B C
G1
K1
G2
K2
G3
K3
B
N
120 VAC
CARD RACK
120 Volt input from control circuit
A B C
2 4 2 4 2 4
G6 K6 G5 K5 G4 K4

SYSTEM CONTROLS A.C. S.S BELT CONTROL
POWER SCHEMATIC

STUDY QUESTIONS

UNIT: 17 SCHEMATICS: BELT STARTER

1. HOW MANY CARDS ARE THERE IN THE CARD RACK?

2. ONE CARD IS DIFFERENT FROM THE OTHERS. WHAT IS ITS NAME? WHERE IS IT LOCATED?

3. WHICH SCR'S WOULD BE CONDUCTING IF LINE #1 IS NEGATIVE?

4. WHAT IS THE PURPOSE OF THE CURRENT TRANSFORMER?

5. USE THE DIAGRAM IN THE HANDOUT. TRACE THE DIRECTION THAT CURRENT FLOWS WHEN SCR #2 IS NEGATIVE.

STUDENT COMPETENCY SHEET #1

UNIT: 18 CIRCUIT CONNECTIONS: BELT STARTER

COMPETENCY STATEMENT: CONNECTS SOLID STATE CONTROLLERS, MOTORS, AND POWER SOURCES FOR BELT STARTER

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL CONNECT A SOLID STATE BELT STARTER TO A MOTOR, A POWER SOURCE. YOU WILL ALSO CONNECT THE EXTERNAL CONTROL SWITCHES NECESSARY FOR ITS OPERATION.

CONDITIONS: YOU HAVE 30 MINUTES TO DO ALL WORK. YOU HAVE THESE ITEMS TO WORK WITH: SOLID STATE CONTROLLER FOR A BELT STARTER, AN AC MOTOR, A THREE-PHASE AC POWER SOURCE, HAND TOOLS, MANUFACTURER'S INSTALLATION INSTRUCTION MANUAL, SCHEMATIC DIAGRAM, WIRING DIAGRAM, AND VOM.

STANDARD: THIS IS HOW WELL YOU MUST DO:

1. ALL METER READINGS MUST BE LIKE THOSE IN THE MANUAL AND ON THE DIAGRAMS.
2. THE BELT STARTER MUST WORK LIKE IT SHOULD.
3. YOU MUST WORK SAFELY AND NOT DAMAGE TOOLS OR PARTS.
4. YOU MUST GET DONE IN 30 MINUTES.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "INSTALLATION OF THE SOLID STATE BELT STARTER" FROM THE INSTRUCTOR, READ IT.
2. GET STUDENT HANDOUT #2, "BELT STARTER CONNECTIONS," FROM THE INSTRUCTOR. DO WHAT IT SAYS ON THE HANDOUT.
3. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
INSTALLATION OF THE SOLID STATE BELT STARTER

UNIT: 18 CIRCUIT CONNECTIONS: BELT-STARTER

WHEN A NEW SOLID STATE BELT STARTER IS DELIVERED AND IS TO BE INSTALLED SEVERAL THINGS MUST BE CHECKED. THESE THINGS INCLUDE THE FOLLOWING:

1. THE SIZE AND VOLTAGE RATING OF THE BELT STARTER.
2. THE SIZE AND VOLTAGE RATING OF THE MOTOR.
3. THE POWER SUPPLY AVAILABLE.
4. THE NUMBER AND KINDS OF PROTECTIVE DEVICES TO BE USED.
5. OTHER DEVICES TO BE OPERATED BY THE BELT STARTER.

INITIAL PROCEDURE:

1. CHECK THE VOLTAGE OF THE POWER SUPPLY, THE MOTOR, AND THE STARTER TO SEE THAT THEY ARE COMPATIBLE WITH EACH OTHER. MOST STARTERS OPERATE AT 240/480 VOLTS.
   A. THE MOTOR'S NAMEPLATE WILL GIVE THIS INFORMATION FOR THE MOTOR.
   B. THE NAMEPLATE ON THE STARTER WILL GIVE INFORMATION FOR OPERATING VOLTAGES AND CURRENT (MOTOR SIZE) LIMITATIONS FOR THE STARTER. THE MANUFACTURER'S INSTRUCTIONS AND ELECTRICAL DIAGRAMS SHOULD BE USED.
2. FEDERAL AND STATE LAWS AND COMPANY REQUIREMENTS WILL

USUALLY LET YOU KNOW WHAT PROTECTIVE DEVICES MUST BE ON THE BELT STARTER. THESE MAY INCLUDE SOME OR ALL OF THE FOLLOWING:

A. REMOTE STARTING AND STOPPING OF THE BELT MOTOR.
B. OVERLOAD PROTECTION.
C. SEQUENCE CONTROL (WHERE MORE THAN ONE BELT STARTER IS OPERATED).
D. BELT SLIP CONTROL.
E. AUTOMATIC FIRE PROTECTION USING HEAT SENSORS.
F. AUTOMATIC BELT TENSIONING DEVICES.

CONNECTING THE POWER CIRCUIT

AFTER DETERMINING THAT THE POWER SUPPLY, THE BELT STARTER, AND THE MOTOR ARE ALL COMPATIBLE THE POWER CIRCUIT CONNECTIONS CAN BE MADE. YOU WOULD USE THE ELECTRICAL DIAGRAMS TO DO THE FOLLOWING:

1. CONNECT THE THREE PHASE POWER SOURCE TO THE LINE SIDE TERMINALS OF THE MAIN CIRCUIT BREAKER. ALL WIRING MUST CONFORM WITH FEDERAL, STATE, AND LOCAL ELECTRICAL CODES.
2. CONNECT THE MOTOR LEADS TO THE THREE BELT STARTER TERMINALS MARKED T1, T2, T3. THESE TERMINALS ARE AT THE SCR'S. THIS COMPLETES THE POWER CIRCUIT CONNECTIONS. AT THIS TIME DURING THE INSTALLATION THE STARTER WOULD NOT BE ENERGIZED.

CONNECTING THE CONTROL CIRCUIT

1. CHECK THE CONTROL TRANSFORMER CONNECTIONS, PHASE LAMP CONNECTIONS, AND CARD RACK CONNECTIONS TO MAKE CERTAIN THEY ARE CONNECTED FOR THE PROPER VOLTAGE. (MOST CONTROL TRANSFORMERS ARE DESIGNED FOR DUAL VOLTAGE OPERATION).
2. CHECK THE ELECTRICAL DIAGRAMS TO FIND OUT WHAT CONTROL FUNCTIONS ARE PROVIDED AND WHERE THEY ARE TO BE CONNECTED. (THIS WILL MEAN CHECKING BOTH THE SCHEMATIC AND THE WIRING DIAGRAM.)
3. INSTALL WIRING FROM EXTERNAL SWITCHES AND PROTECTIVE DEVICES TO THE PANEL. AGAIN, THIS WIRING MUST CONFORM TO ALL ELECTRICAL CODES AND COMPANY SPECIFICATIONS.
4. CONNECT THE PROTECTIVE DEVICES AS SHOWN ON THE ELECTRICAL DIAGRAMS. IF THE NUMBER OF CONNECTIONS MADE ARE DIFFERENT FROM THOSE SHOWN ON THE DIAGRAMS, THE DIAGRAMS SHOULD BE CHANGED TO SHOW THE CHANGES. THIS WILL BE OF HELP LATER WHEN TROUBLESHOOTING IS NECESSARY.

CHECKING THE INSTALLATION

AFTER THE INSTALLATION HAS BEEN COMPLETED IT SHOULD BE CHECKED BEFORE THE STARTER IS ENERGIZED.

1. RE-CHECK ALL POWER CIRCUIT AND CONTROL CIRCUIT CONNECTIONS.
2. REMOVE THE FUSES FROM THE CONTROL CIRCUIT.
3. PLACE THE MAIN CIRCUIT BREAKER IN THE "ON" POSITION.

4. USE A VOLTMETER TO CHECK THE VOLTAGE AT THE SECONDARY TERMINALS OF THE CONTROL TRANSFORMER. THE READING SHOULD BE 120 VOLTS.
5. TURN OFF THE MAIN CIRCUIT BREAKER AND REPLACE THE CONTROL FUSES.
6. WITH THE CONTROL SWITCH IN THE "OFF" POSITION, TURN THE MAIN CIRCUIT BREAKER ON. THE "POWER ON" LAMP SHOULD SHOW THAT THE POWER IS "ON." IF NOT, CHECK FOR BAD FUSES.
7. PLACE THE CONTROL SWITCH IN THE "AUTOMATIC" POSITION. THE BELT MOTOR SHOULD START AND ACCELERATE TO FULL SPEED. IF NOT, A CONTROL LAMP WILL SHOW THE TROUBLE.
8. CHECK ALL SAFETY SWITCHES TO SEE THAT THEY WILL FUNCTION CORRECTLY.
9. CHECK THE CONTROL SWITCH IN THE "HAND" POSITION.
10. CHECK THE CONTROL SWITCH IN THE "OFF" POSITION.

STUDENT HANDOUT #2
BELT STARTER CONNECTIONS

Unit: 18 Circuit Connections: Belt Starter

Do these things:

1. Get these things and go to the Solid State AC Belt Starter: hand tools, VOM, manufacturer's installation instruction manual, schematic diagram, and wiring diagram.
2. Check your diagrams with the panel. Are they the same? If not, make changes on your diagrams and have the instructor check them.
3. What is the line voltage in the training center? Check it with your VOM. Write the voltage reading here _________.
4. Make sure all power is disconnected. Connect the line side terminals to the power source.
5. Connect the load side terminals to the motor.
6. Connect the external switches to the control circuit. There are four switches: pressure, remote, sequence, and speed.
7. Check to make sure the control circuit is connected correctly.
8. Have the instructor check you work. Make any changes you are told to do.
9. Remove the fuses from the Control Circuit.

10. ENERGIZE THE STARTER.

11. MEASURE THE LINE VOLTAGE AND CONTROL VOLTAGE WITH YOUR VOM. WRITE THE VOLTAGE READINGS HERE.

LINE VOLTAGE ________________

CONTROL VOLTAGE ______________

12. HAVE THE INSTRUCTOR CHECK YOUR WORK. MAKE ANY CHANGES YOU ARE TOLD TO DO.

13. TURN OFF THE BREAKER AND REPLACE THE CONTROL FUSES.

14. NOW START THE MOTOR. DOES IT DO EVERYTHING IT SHOULD?

STUDENT COMPETENCY SHEET #1

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

COMPETENCY STATEMENT: TROUBLESHOOTS AC/SOLID STATE BELT-STARTER PANEL BY SPECIFYING PROBABLE CAUSES FOR MALFUNCTIONS, RECOMMENDING SERVICE PROCEDURES, AND LOCATING AND CORRECTING FAULTS.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL TROUBLESHOOT AN AC/SOLID STATE BELT STARTER PANEL.

CONDITIONS: YOU WILL BE TOLD TWO OR THREE PROBLEMS FOR AN AC/SOLID STATE BELT STARTER PANEL. YOU HAVE THREE ITEMS TO WORK WITH: AC/SOLID STATE BELT STARTER PANEL, VOM, HANDTOOLS, SCHEMATIC DIAGRAMS, WIRING DIAGRAMS, AND TROUBLESHOOTING GUIDE. YOU HAVE 30 MINUTES TO CORRECT EACH PROBLEM.

STANDARD: THIS IS HOW WELL YOU MUST DO:

1. FOR EACH PROBLEM YOU MUST LIST SOME CAUSES.
2. FOR EACH CAUSE YOU LIST YOU MUST LIST A REPAIR OR SERVICE PROCEDURE.
3. YOU MUST CORRECT EACH PROBLEM AND TAKE THE METER READINGS THAT SHOW THAT THE PANEL WORKS THE WAY IT SHOULD.

4. You must work safely and not damage tools or parts.
5. You must correct each problem in 30 minutes.

Learning Activities:

1. Get Student Handout #1, "Meter Readings: Belt-Starter Panel," from the instructor. Do all the things listed on the handout.
2. Get Student Handout #2, "Solid State Belt Starter: Troubleshooting Guide," from the instructor. Read it and do the problems at the end of it.
3. Your instructor has some troubleshooting problems for the solid state belt-starter panel. Go get one and complete it.
4. Complete as many troubleshooting problems as your instructor tells you to.
5. Tell the instructor when you are ready for the examination. Complete the examination.

STUDENT HANDOUT #1

METER READINGS: BELT STARTER PANEL

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

DO THESE THINGS:

1. GET SCHEMATIC AND WIRING DIAGRAMS FOR THE BELT STARTER PANEL. GO TO THE PANEL. ANSWER THESE QUESTIONS:

   A. WHERE WOULD YOU CONNECT A VOM TO SEE IF THE BELT STARTER PANEL WAS CONNECTED TO THE CORRECT POWER SOURCE?

   B. WHAT VOLTAGE READING SHOULD YOU GET WHEN YOU CONNECT YOUR VOM LIKE YOU SAID IN #A?

   C. WHERE WOULD YOU CONNECT A VOM TO SEE IF THERE IS CONTROL VOLTAGE FOR THE BELT STARTER PANEL?

   D. WHAT VOLTAGE READING SHOULD YOU GET WHEN YOU CONNECT YOUR VOM LIKE YOU SAID IN #C?

   E. WHERE WOULD YOU CONNECT A VOM TO SEE IF THE BELT STARTER CARD RACK HAD POWER CONNECTED TO IT?

F. WHAT VOLTAGE READING SHOULD YOU GET WHEN YOU CONNECT YOUR VOM LIKE YOU SAID IN #E?

G. WHAT VOM READING COULD YOU MAKE TO SEE IF THE WHOLE CONTROL CIRCUIT TO THE RR COIL IS READY TO OPERATE?

H. IF YOU TOOK THESE VOM READINGS: A, C, E, & G, COULD YOU TELL IF THE BELT STARTER PANEL WOULD WORK LIKE IT SHOULD?

HAVE YOUR INSTRUCTOR CHECK YOUR WORK.

2. TAKE YOUR VOM AND USE YOUR SCHEMATIC AND WIRING DIAGRAMS AND MAKE THESE READINGS: A, C, E, & G. WRITE YOUR READINGS DOWN. SHOW THEM TO THE INSTRUCTOR. EXPLAIN WHY YOU THINK THE PANEL WOULD WORK.

STUDENT HANDOUT #2

Unit: 19 Troubleshooting: Belt-Starter

Solid State Belt Starter: Troubleshooting Guide

SYMPTOM: Motor will not start

Probable Cause	How to Determine Cause
1. No power	1. Check to determine if the main circuit breaker is tripped. If not tripped, 2. Check voltage on load side of main circuit breaker. Voltage should be 240 volts between any two phase wires.
2. No control circuit power	1. Visually check "Power On" indicating light. If off, 2. Check for defective control fuse. If fuse ok, 3. Check output of control transformer. Control voltage should be 120 volts.
3. One or more control switches in abnormal condition. These include the following: a. Hand/Auto/Off b. Sequence c. Remote d. Take-up e. Belt Slip f. Overload	1. Visually check panel indicating lamps to determine which of the switch conditions exist. 2. Determine cause for condition. A. Sequence switch: Is other belt operating or is switch defective? B. Remote Switch: Are remote switches off or defective? C. Take-Up: Is take-up mechanism functioning or is pressure switc in the take-up mechanism defective? D. Overload: Does an overload exist? Why?

SYMPTOM: Motor will not start (continued)

Probable Cause	How to Determine Cause
4. Card rack malfunction	1. Check for voltage at the input terminals of the card rack. Voltage should be 120 volts AC. If input voltage is ok,
	2. Check the master sensor card for tightness. If card is tight,
	3. Check output voltage at the SCR terminals. If no voltage is available, replace master sensor card.
5. Burned out motor or connections in the motor circuit between the starter and the motor.	1. Check voltage at load side of the SCR's. Should be 240 volts between each phase wire.

SYMPTOM: Motor hums, but will not start.

Probable Cause	How to Determine Cause
1. Single phasing condition at the main power supply	1. Measure voltage at both line and load side of the main circuit breaker. Correct voltage between any two phase wires should be 240 volts AC. If the voltage is ok,
2. Loose firing card in card rack	1. Check to see if all cards are tight. Try to re-start motor. If cards are tight and motor will not start, check for defective firing card by,
3. Defective firing card	1. Removing one card at a time. Try to start motor without the card. a. If the motor hums and tries to start the card you removed is defective.

	b. If motor does not start the card you removed is 2. Remove another card, repeat above procedure.
4. Defective motor, or wiring from starter to the motor.	1. Check voltage at the motor of the starter. The vo should be 240 volts. is ok. 2. Check voltage at the a. If voltage is ok, is defective. b. If voltage is not ok, wiring between start motor is open.
Defective or open gate lead to SCR's in one phase of the starter.	1. Check for voltage at the No reading means an open gate lead. If voltage is ok,
Two SCR's defective (open) in one of the phases of the starter. This condition is unlikely because SCR's seldom fail open circuited and both SCR's must be open.	1. Check each SCR using an ohm A good SCR will give the readings: a. The resistance betw Anode and Cathode will 50,000 ohms or higher in either direction. b. The Gate to Cathode resis will be between 10 and ohms resistance in at one direction.

SYMPTOM: Motor tries to start across-the-line when the main circuit breaker is closed.

Probable Cause	How to Determine Ca
1. All SCR's are shorted	1. Check each SCR using an ohm A good SCR will give the fo readings: a. The resistance between t Anode and Cathode will 50,000 ohms or higher i either direction. b. The Gate to Cathode resi will be between 10 and ohms resistance in one direction.

SYMPTOM: Motor hums when main circuit breaker is closed.

Probable Cause	How to Determine Cause
1. Two SCR's shorted in two different phases.	1. Check SCR's using the ohmmeter. A good SCR will give the following readings: a. The resistance between the Anode and Cathode will be 50,000 ohms or higher in either direction. b. The Gate to Cathode resistance will be between 10 and 100 ohms resistance in at least one direction.

SYMPTOM: Motor delays before starting.

Probable Cause	How to Determine Cause
1. Master sensor card needs adjustment.	1. Adjust ramp and step potentiometer for desired starting. If motor delays, check
2. Master sensor card defective.	1. Replace master sensor card.

SYMPTOM: Motor accelerates too fast.

Probable Cause	How to Determine Cause
1. Master sensor card in card rack improperly adjusted.	1. Adjust Step Potentiometer, and Ramp Potentiometer located on master sensor card until desired acceleration is obtained. If motor still accelerates too fast,
2. Defective current transformer or wiring.	1. Connect ammeter across the terminals of the current transformer. Should be 1/40 of actual motor current.

	2. Check current transformer input at card rack. If low or no amperage, wiring defective.
3. Defective master sensor card.	1. If above checks are ok and motor still accelerates too fast, change the master sensor card.

SYMPTOM: Motor speed or acceleration is erratic.

Probable Cause	How to Determine Cause
1. Loose firing cards.	1. Check for tightness. If cards are tight, check
2. Pre-mature firing	1. Check resistor and capacitor ratings.
	2. Turn off power and check resistor/capacitor circuits with ohmmeter.

PROBLEMS FOR STUDENT HANDOUT #2

TAKE YOUR VOM, PRINTS, AND TROUBLESHOOTING GUIDE AND GO TO THE BELT STARTER PANEL. DO THESE PROBLEMS.

1. CHECK THE VOLTAGE ON LOAD SIDE OF MAIN CIRCUIT BREAKER.
   READING ________________

2. CHECK THE VOLTAGE AT THE INPUT TERMINALS OF THE CARD RACK. READING ________________

3. CHECK THE OUTPUT VOLTAGE AT THE SCR TERMINALS.
   READING ________________

4. CHECK AN SCR WITH AN OHMMETER.
   READINGS ____________________

5. CHECK CURRENT TRANSFORMER WITH AN AMMETER.
   READING ____________________

6. CHECK RESISTOR/CAPACITOR CIRCUIT FOR AN SCR WITH AN OHMMETER. READINGS __________________

PROBLEM #1

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR WILL NOT START

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #2

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR HUMS, BUT WILL NOT START.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #3

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR HUMS.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ________________
   (B) ________________
   (C) ________________
   (D) ________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #4

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR DELAY BEFORE STARTING

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #5

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR ACCELERATES TOO FAST.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #6

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR SPEED IS ERRATIC.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #7

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR WILL NOT START

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A)

   (B)

   (C)

   (D)

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #8

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR RUNS, SHUT MOTOR DOWN, MOTOR RESTARTS BUT JUST HUMS.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A)
   (B)
   (C)
   (D)

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #9

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR WILL NOT START.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
    (A)
    (B)
    (C)
    (D)
    (E)
    (F)
    (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
    (A)
    (B)
    (C)
    (D)

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #10

UNIT: 19 TROUBLESHOOTING: BELT-STARTER

PROBLEM: MOTOR STARTS ACROSS-LINE AT FULL SPEED.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)
2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A)
   (B)
   (C)
   (D)
3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

STUDENT COMPETENCY SHEET #1

UNIT: 20 SOLID STATE, BATTERY POWERED: COMPONENTS

COMPETENCY STATEMENT: IDENTIFIES AND EXPLAINS FUNCTION OF COMPONENTS ON SOLID STATE, BATTERY POWERED PANEL.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL DO THESE TWO THINGS:

1. IDENTIFY MAJOR COMPONENTS ON A SOLID STATE, BATTERY POWERED PANEL.
2. ANSWER QUESTIONS ABOUT HOW MAJOR COMPONENTS ON A SOLID STATE, BATTERY POWERED PANEL FUNCTION.

CONDITIONS: FIFTEEN COMPONENTS WILL BE TAGGED ON THE SOLID STATE, BATTERY POWERED PANEL. YOU WILL HAVE 30 MINUTES TO DO ALL WORK. YOU MAY NOT USE REFERENCES.

STANDARDS: ALL YOUR ANSWERS MUST BE CORRECT.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, "COMPONENT IDENTIFICATION," FROM THE INSTRUCTOR. READ IT.
2. GET ANOTHER STUDENT. GO TO THE SOLID STATE, BATTERY POWERED TRAINING PANEL. PRACTICE FINDING THE MAJOR COMPONENTS.

3. GET STUDENT HANDOUT #2, "COMPONENT FUNCTION AND PURPOSE," FROM THE INSTRUCTOR. READ IT. ANSWER THE QUESTIONS AT THE END OF THE HANDOUT.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
COMPONENT IDENTIFICATION

UNIT: 20 SOLID STATE, BATTERY POWERED: COMPONENTS

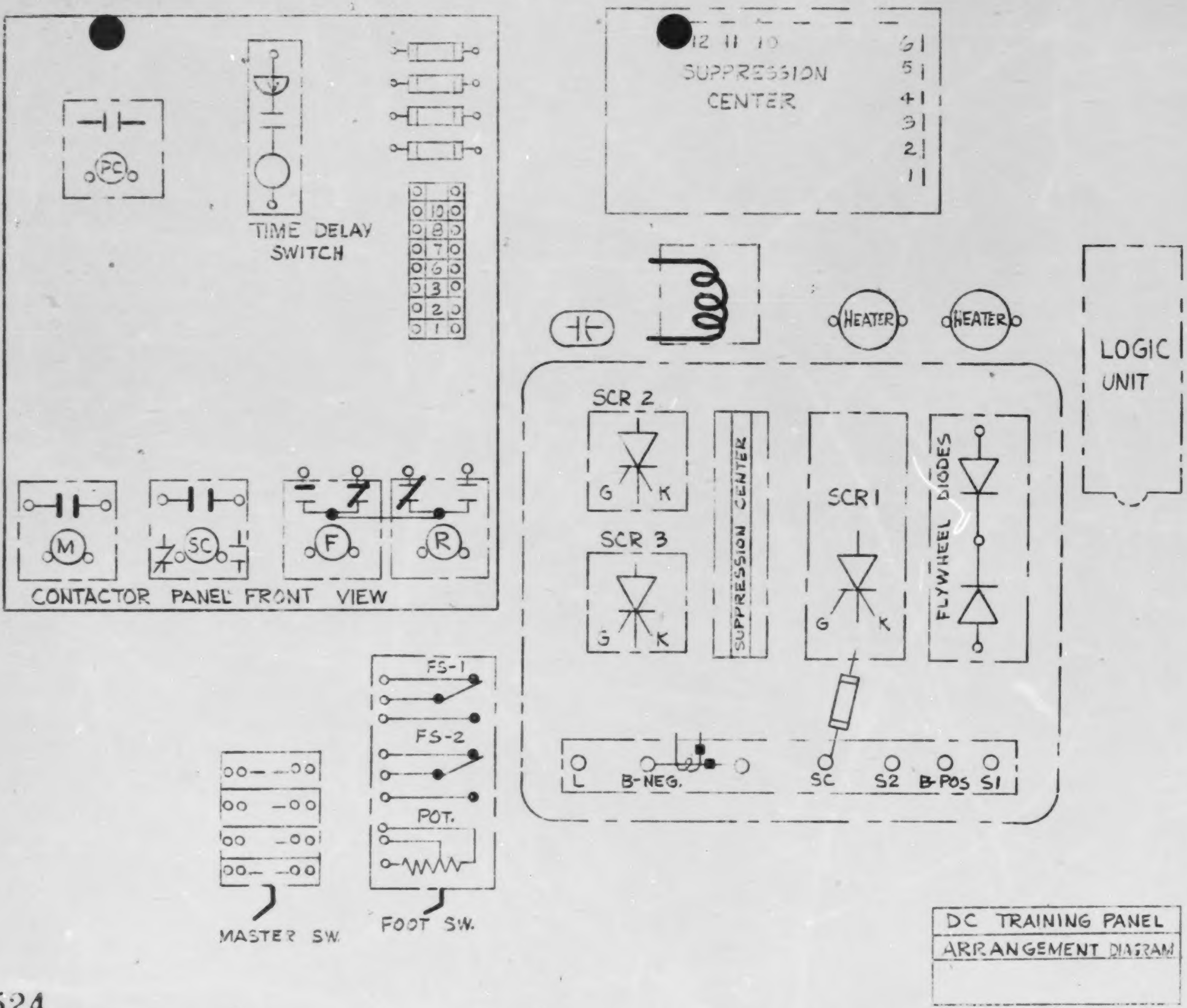
AT THE END OF THIS HANDOUT, YOU WILL FIND AN ARRANGEMENT DIAGRAM FOR THE BATTERY POWERED TRAINING PANEL USED IN THIS PROGRAM. GET THE DIAGRAM AND STUDY IT FOR A FEW MOMENTS.

GO TO THE PANEL. USE THE DIAGRAM AND IDENTIFY THE MAJOR COMPONENTS ON THE PANEL. YOU SHOULD LOOK FOR THESE COMPONENTS:

1. THE SOLID STATE PANEL CONSISTING OF:
    - A. THREE SCR'S
        - (1) THE MAIN OR NO. 1 SCR
        - (2) THE OFF OR NO. 2 SCR
        - (3) THE REVERSAL OR NO. 3 SCR
    - B. FLYWHEEL DIODES
    - C. SUPPRESSION CENTER ASSEMBLY
    - D. POWER TERMINAL STRIP
2. THE LOGIC UNIT
3. THE CAPACITOR BANK. ONLY ONE CAPACITOR IS USED FOR THE TRAINING PANEL. ONE EQUIPMENT SIZE AND NUMBER OF CAPACITORS WILL DEPEND UPON WHAT SIZE MOTOR IS USED.
4. THE COMMUTATING COIL
5. THE FOOT SWITCH ASSEMBLY
6. THE MASTER SWITCH

7. THE CONTACTOR PANEL BOARD WHICH HAS THE FOLLOWING:

   A. MAIN CONTACTOR
   B. FORWARD CONTACTOR
   C. REVERSE CONTACTOR
   D. BY-PASS (SC) CONTACTOR
   E. PUMP (PC) ACCELERATING CONTACTOR
   F. TIME DELAY
   G. CONTROL FUSES
   H. TERMINAL STRIP


PC
TIME DELAY SWITCH
10
8
7
6
3
2
1
12 11 10
SUPPRESSION CENTER
6
5
4
3
2
1
HEATER
HEATER
LOGIC UNIT
SCR 2
G K
SCR 3
G K
SUPPRESSION CENTER
SCR 1
G K
FLYWHEEL DIODES
M
SC
F
R
CONTACTOR PANEL FRONT VIEW
FS-1
FS-2
POT.
MASTER SW.
FOOT SW.
L
B-NEG.
SC
S2
B-POS
S1

DC TRAINING PANEL
ARRANGEMENT DIAGRAM

STUDENT HANDOUT #2
COMPONENT FUNCTION AND PURPOSE

UNIT: 20 SOLID STATE, BATTERY POWERED: COMPONENTS

NOW THAT WE HAVE LEARNED THE NAMES AND LOCATION OF THE MAJOR COMPONENTS OF THE BATTERY POWERED TRAINING PANEL, LETS LOOK AT HOW THEY ARE USED.

SINCE WE HAVE STUDIED THE POWER CIRCUIT OF THE PANEL IN AN EARLIER LESSON THIS HANDOUT WILL BE BRIEF. DIAGRAMS FOR THE POWER AND CONTROL CIRCUITS ARE ATTACHED TO THE END OF THE HANDOUT FOR YOUR REFERENCE.

SCR's

THERE ARE THREE SCR'S. THE "MAIN" SCR IS USED TO CONDUCT CURRENT TO THE MOTOR. THE "OFF" SCR IS USED TO CHARGE THE CAPACITOR. IT IS ALSO USED TO CONNECT THE CAPACITOR TO THE "MAIN" SCR CAUSING REVERSE BIASING. THIS INTERRUPTS CURRENT THROUGH IT AND CAUSES IT TO RETURN TO THE BLOCKING STATE. THE "REVERSAL" SCR IS USED TO PERMIT THE CAPACITOR TO DISCHARGE THROUGH THE INDUCTION COIL AND TO CHARGE THE CAPACITOR WITH A REVERSE POLARITY.

FLYWHEEL DIODES

THERE ARE TWO FLYWHEEL DIODES. THEY ARE CONNECTED TO PERMIT

INDUCED MOTOR CURRENT TO FLOW THROUGH THE MOTOR WINDINGS WHILE THE "MAIN" SCR IS BLOCKING. ONE OF THE DIODES IS USED FOR FORWARD OPERATION AND THE OTHER IS USED FOR REVERSE OPERATION.

SUPPRESSION CENTER ASSEMBLY

THE SUPPRESSION CENTER ASSEMBLY SERVES SEVERAL PURPOSES.

1. IT CONTAINS THE FIRING CIRCUITS FOR THE SCR'S. THAT'S RIGHT, THE FIRING CIRCUITS ARE LOCATED ON THE SUPPRESSION CENTER ASSEMBLY, AND NOT IN THE LOGIC UNIT. THE LOGIC UNIT SIGNALS THE FIRING CIRCUITS WHEN TO TRIGGER THE SCR'S.
2. IT PREVENTS PREMATURE OR DELAYED FIRING OF THE SCR'S DUE TO INDUCTANCE.
3. IT PROTECTS THE SCR'S FROM DAMAGE DUE TO HIGH INDUCTIVE VOLTAGES.

LOGIC UNIT

THE LOGIC UNIT IS THE ELECTRICAL BRAIN FOR THE ENTIRE CONTROL CIRCUIT.

1. IT IS ENERGIZED WHENEVER THE MASTER CONTROL SWITCH IS PLACED IN THE FORWARD OR REVERSE POSITION.
2. IT RECEIVES A SIGNAL FROM THE MICRO SWITCH (FS-1) IN THE FOOT SWITCH. WHEN THIS SWITCH IS CLOSED, THE LOGIC UNIT COMPLETES THE CONTROL CIRCUIT FROM THE FORWARD OR REVERSE OPERATING COIL AND CUASES THE CONTACTOR TO CLOSE.

3. It receives a signal from the potentiometer in the foot switch. This signal determines the speed at which the SCR's are triggered.
4. It receives a signal from the micro switch (FS-2) in the foot switch. When the foot pedal is fully depressed, the logic unit causes the by-pass contactor (SC) to close. The by-pass contactor will close when the SCR's are firing at their maximum rate of speed.
5. It prevents the operator from reversing the motor without first returning the foot switch to the zero speed setting.

Capacitor bank and Commutating Coil

The capacitor bank and the commutating coil work together. They provide a reverse bias necessary to turn off the "Main" SCR.

FOOT SWITCH

The foot switch has two micro switches and a potentiometer. One portion of the master control switch connects power to the micro switch (FS-1). When the foot switch is depressed the FS-1 switch closes . This connects power to the directional control portion of the master switch. Under these conditions the logic unit will permit the operating coil of the directional contactor to close.

DEPRESSING THE FOOT SWITCH FURTHER CAUSES THE POTENTIOMETER TO ROTATE. AS THE RESISTANCE CHANGES THE LOGIC UNIT BEGINS TO SIGNAL THE FIRING CIRCUITS LOCATED ON THE SUPPRESSION CENTER TO START TRIGGERING THE SCR'S. WHEN THE POTENTIOMETER HAS BEEN ROTATED TO THE END OF ITS TRAVEL, THE SCR'S WILL BE FIRING AT THEIR MAXIMUM RATE. THIS IS ABOUT 300 TIMES PER SECOND. WHEN THE FOOT SWITCH IS DEPRESSED ALL THE WAY THE OTHER MICRO SWITCH (FS-2) WILL CLOSE. THE LOGIC UNIT RECEIVES A SIGNAL TO CLOSE THE BY-PASS CONTACTOR. THIS CONNECTS THE MOTOR ACROSS-THE-LINE FOR FULL SPEED OPERATION.

MASTER SWITCH

THE MASTER SWITCH CONSISTS OF SEVERAL SNAP-ACTION SWITCHES GROUPED TOGETHER WITH ONE OPERATING HANDLE.

ONE STAGE OF THE SWITCH ENERGIZES THE FOOT SWITCH, LOGIC UNIT, THE MAIN CONTACTOR OPERATING COIL, AND THE PUMP MOTOR ACCELERATING CONTACTOR (PC).

THE REMAINING STAGES OF THE MASTER SWITCH CONNECT ONE OF THE CONTROL POWER LEADS TO THE OPERATING COILS OF THE FORWARD OR REVERSE CONTACTORS. EVEN THOUGH THE DIRECTIONAL CONTROL PORTION OF THE MASTER SWITCH IS CLOSED IN EITHER DIRECTION, THE CIRCUIT IS NOT COMPLETE TO THE OPERATING COILS UNTIL THE LOGIC UNIT DOES ITS PART.

CONTACTOR PANEL BOARD

THE CONTACTOR PANEL BOARD HAS FIVE CONTACTORS, A SOLID STATE TIME DELAY DEVICE, CONTROL FUSES, AND A TERMINAL STRIP.

THE CONTACTORS ARE MUCH LIKE THE CONTACTORS USED IN OTHER PANELS, EXCEPT THAT THEY HAVE A PERMANENT MAGNET BLOW-OUT COIL LOCATED AT THE TOP OF EACH CONTACTOR.

CLOSING THE MAIN CONTACTOR CONNECTS THE NEGATIVE POWER TO THE POWER CIRCUIT OF THE SOLID STATE PANEL AND IT ALSO CONNECTS THE NEGATIVE POWER CIRCUIT TO THE PUMP MOTOR. THE PUMP MOTOR WILL AUTOMATICALLY START. THE OPERATING COIL IS ENERGIZED WHENEVER THE MASTER SWITCH IS PLACED IN THE FORWARD OF REVERSE DIRECTION.

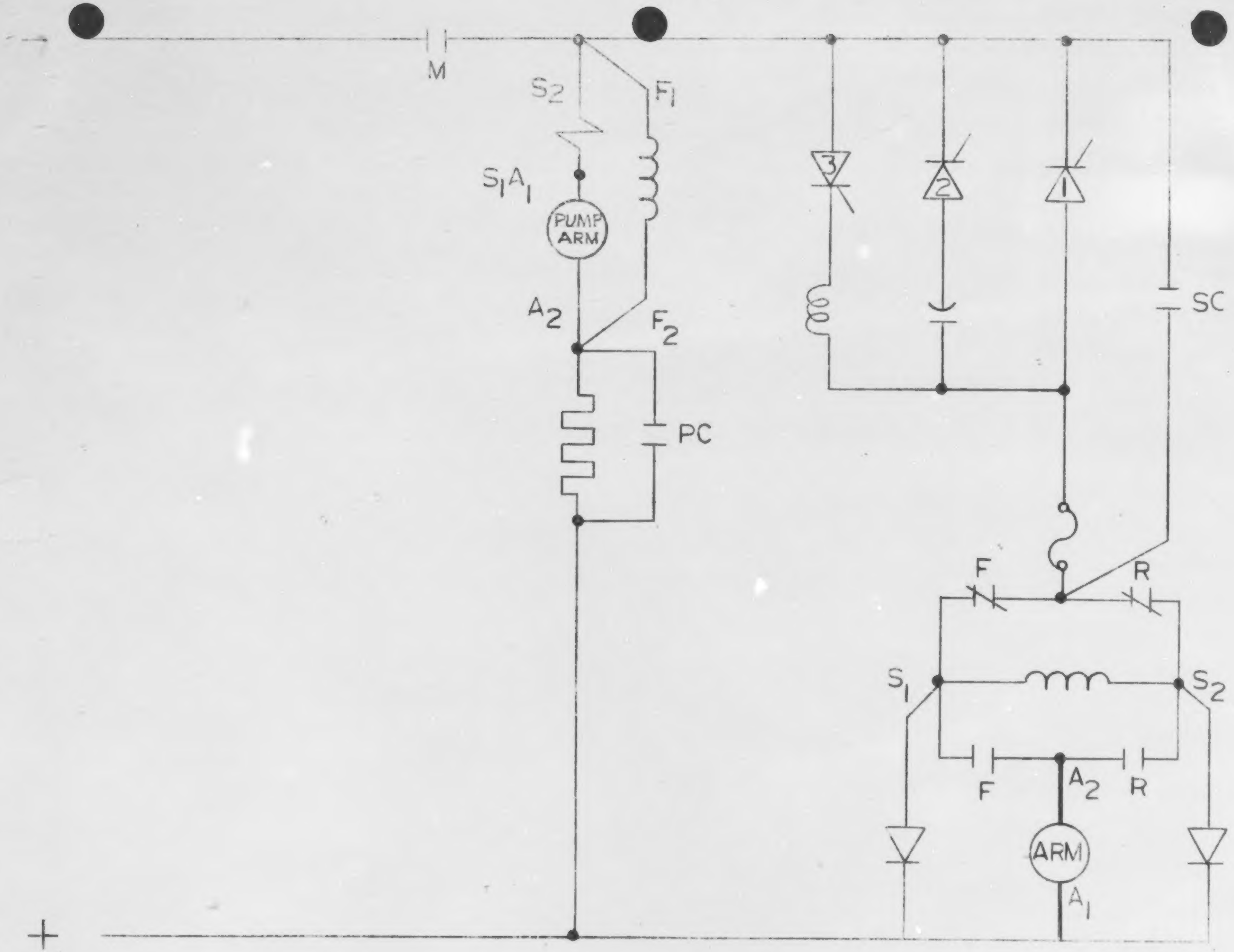
THE (PC) CONTACTOR'S OPERATING COIL IS CONNECTED IN PARALLEL WITH THE MAIN CONTACTOR. IT IS IN SERIES WITH A TIME DELAY DEVICE SO IT WILL CLOSE AUTOMATICALLY AFTER A BRIEF TIME DELAY. WHEN IT CLOSES, THE STARTING RESISTOR IN THE PUMP MOTOR CIRCUIT IS BYPASSED.

THE FORWARD AND REVERSING CONTACTORS ARE DIFFERENT FROM THE OTHERS. THEY EACH HAVE A SET OF NORMALLY OPEN, AND NORMALLY CLOSED POWER CONTACTS. IN OPERATION THEY ARE LIKE TWO SINGLE-POLE DOUBLE-THROW SWITCHES.

THE TOP POWER CONTACTS OF BOTH CONTACTS ARE CONNECTED TOGETHER. THEY ARE ALSO CONNECTED TO THE A-2 ARMATURE LEAD OF THE MOTOR.

THE TWO NORMALLY CLOSED CONTACTS OF BOTH CONTACTORS ARE CONNECTED TOGETHER WITH A BUSS BAR. THIS CONNECTION IS TO THE SC TERMINAL OF THE SOLID STATE PORTION OF THE PANEL AND TO BY-PASS CONTACTOR. THE COMMON CONTACT OF THE FORWARD CONTACTOR CONNECTS TO THE S-1 TERMINAL ON THE SOLID STATE PANEL. THE COMMON CONTACT ON THE REVERSE CONTACTOR CONNECTS TO THE S-2 TERMINAL ON THE SOLID STATE PANEL.

THE SC CONTACTOR SERVES TO BY-PASS THE SOLID STATE PANEL FOR FULL SPEED OPERATION. WHEN IT CLOSES, THE NEGATIVE POWER LEAD IS CONNECTED DIRECTLY TO THE FORWARD/REVERSE CONTACTORS. THIS CONTACTOR ALSO HAS TWO AUXILLIARY CONTACTS WHICH SERVE AS AN ELECTRICAL INTERLOCK.


M
S2
F1
S1A1
PUMP ARM
A2
F2
PC
3
2
1
SC
F
R
S1
S2
F
A2
R
ARM
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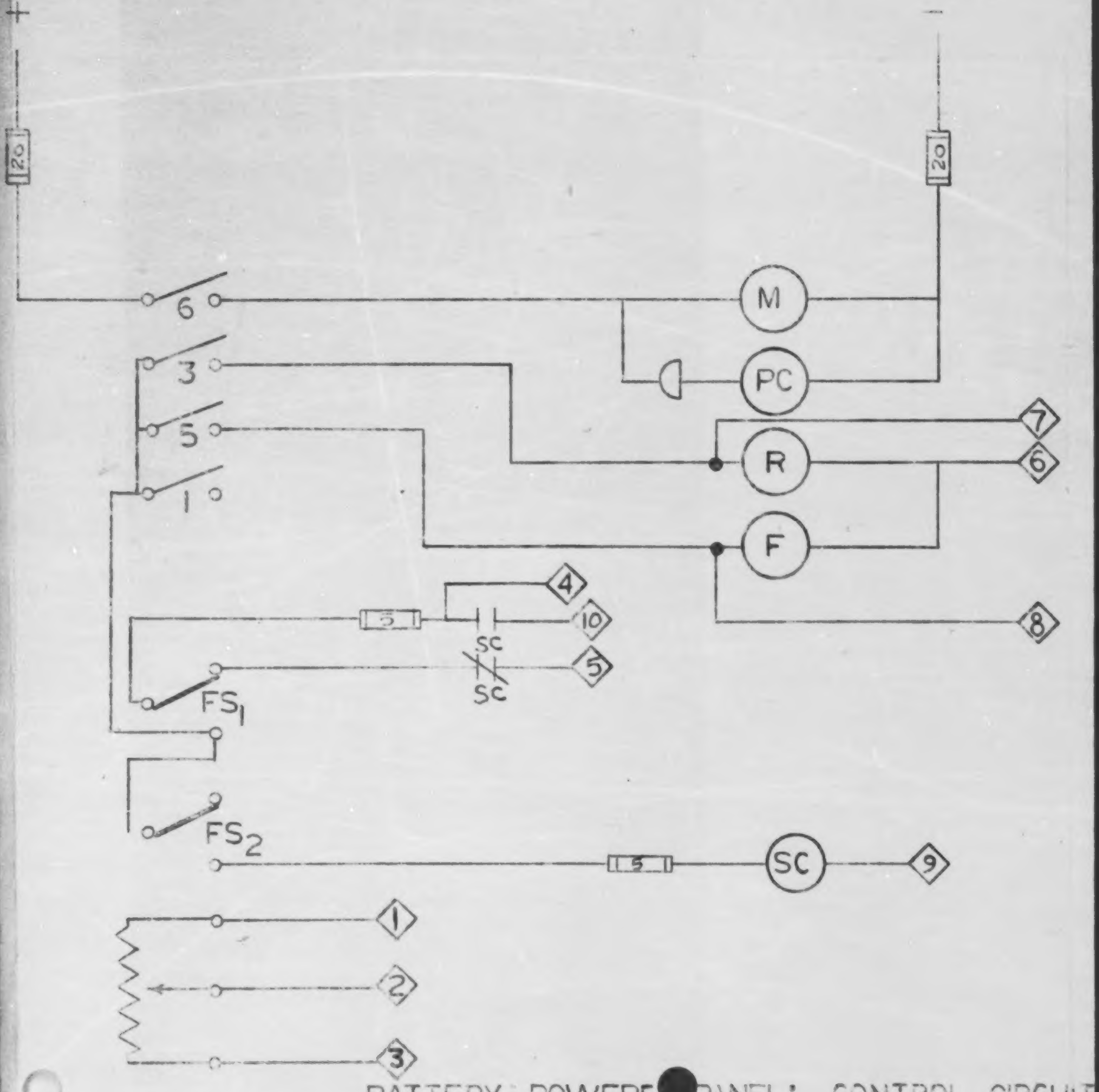
20-12

BATTERY POWERED PANEL: POWER CIRCUIT

532


+
−
20
20
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3
5
1
M
PC
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7
6
8
4
10
5
5
SC
SC
FS1
FS2
5
SC
9
1
2
3

BATTERY POWERED PANEL; CONTROL CIRCUIT

STUDY QUESTIONS

UNIT: 20 SOLID STATE, BATTERY POWERED: COMPONENTS

1. NAME THE THREE SCR'S ON THE PANEL.

   A.

   B.

   C.

2. WHICH SCR IS TURNED OFF WHEN REVERSE BIAS CONDITIONS EXIST?

3. THE SUPPRESSION CENTER ASSEMBLY IS ALL THAT IS NEEDED TO TIME THE "FIRING" OF THE SCR'S ON THE PANEL? CIRCLE THE CORRECT ANSWER. TRUE FALSE

   EXPLAIN YOUR ANSWER.

4. WHICH SIGNAL IS RECEIVED FIRST BY THE LOGIC UNIT? CIRCLE THE CORRECT ANSWER. FS-1 FS-2

5. WHICH SIGNAL IS RECEIVED LAST BY THE LOGIC UNIT? CIRCLE THE CORRECT ANSWER. FS-2 POTENTIOMETER

6. HOW MANY SCR'S ARE USED WHEN THE FOOT SWITCH IS DEPRESSED ALL THE WAY? CIRCLE THE CORRECT NUMBER. 0, 1, 2, 3,

7. WHICH CONTACTOR IS CLOSED WHEN THE MASTER SWITCH IS PLACED IN THE FORWARD OR REVERSE DIRECTION?

STUDENT EXAMINATION #1

UNIT: 20 SOLID STATE, BATTERY POWERED: COMPONENTS

I. GO TO THE SOLID STATE, BATTERY POWERED PANEL. FIFTEEN MAJOR COMPONENTS HAVE BEEN TAGGED. WRITE THE NAME OF THE COMPONENT IN THE BLANK BY THE NUMBER.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________

II. ANSWER THESE QUESTIONS.

1. WHICH SCR IS USED TO CHARGE THE CAPACITOR? CIRCLE THE CORRECT LETTER.

   A. MAIN

   B. OFF

   C. REVERSAL

2. THE SUPPRESSION CENTER ASSEMBLY CAN TRIGGER AN SCR AT ANY TIME BECAUSE IT CONTAINS THE FIRING CIRCUITS? CIRCLE THE CORRECT LETTER.

   A. TRUE

   B. FALSE

3. HOW IS THE LOGIC UNIT ENERGIZED?

4. WHY DOES THE PANEL HAVE A CAPACITOR AND COMMUTATING COIL?

5. WHICH CONTACTOR IS CLOSED BY MICRO-SWITCH FS-2?

6. WHICH OF THE FOLLOWING KEEPS THE OPERATOR FROM REVERSING THE MOTOR WITHOUT FIRST RETURNING TO A ZERO SPEED SETTING? CIRCLE THE CORRECT LETTER.

   A. LOGIC UNIT

   B. FOOT SWITCH

   C. MASTER SWITCH

7. EXPLAIN HOW THE SC CONTACTOR WORKS.

STUDENT COMPETENCY SHEET #1

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

COMPETENCY STATEMENT: TROUBLESHOOTS SOLID STATE, BATTERY POWERED PANEL BY SPECIFYING PROBABLE CAUSES FOR MALFUNCTIONS, RECOMMENDING SERVICE PROCEDURES, AND LOCATING AND CORRECTING FAULTS.

PERFORMANCE OBJECTIVE:

ACTION: YOU WILL TROUBLESHOOT A SOLID STATE, BATTERY POWERED PANEL.

CONDITIONS: YOU WILL BE TOLD TWO OR THREE PROBLEMS FOR A SOLID STATE, BATTERY POWERED PANEL. YOU HAVE THESE ITEMS TO WORK WITH: SOLID STATE, BATTERY POWERED PANEL, VOM, HANDTOOLS, CONTROL AND POWER CIRCUIT DIAGRAMS, AND TROUBLESHOOTING GUIDE. YOU HAVE 30 MINUTES TO CORRECT EACH PROBLEM.

STANDARDS: THIS IS HOW WELL YOU MUST DO:

1. FOR EACH PROBLEM YOU MUST LIST SOME CAUSES.
2. FOR EACH CAUSE YOU LIST YOU MUST LIST A REPAIR OR SERVICE PROCEDURE.
3. YOU MUST CORRECT EACH PROBLEM AND TAKE THE METER READINGS THAT SHOW THAT THE PANEL WORKS THE WAY IT SHOULD.
4. YOU MUST WORK SAFELY AND NOT DAMAGE TOOLS OR PARTS.

5. YOU MUST CORRECT EACH PROBLEM IN 30 MINUTES.

LEARNING ACTIVITIES:

1. GET STUDENT HANDOUT #1, TROUBLESHOOTING GUIDE, FROM THE INSTRUCTOR. READ IT AND DO THE PROBLEMS AT THE END OF IT.
2. YOUR INSTRUCTOR HAS SOME TROUBLESHOOTING PROBLEMS FOR THE SOLID STATE, BATTERY POWERED PANEL. GO GET ONE AND COMPLETE IT.
3. COMPLETE AS MANY TROUBLESHOOTING PROBLEMS AS YOUR INSTRUCTOR TELLS YOU TO.
4. TELL THE INSTRUCTOR WHEN YOU ARE READY FOR THE EXAMINATION. COMPLETE THE EXAMINATION.

STUDENT HANDOUT #1
TROUBLESHOOTING GUIDE

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

CAUTION: ALWAYS TURN THE POWER OFF AND DISCHARGE THE CAPACITOR BANK BEFORE REMOVING ANY PARTS OR CONNECTING OR DISCONNECTING ANY WIRING. USE A 100 OHM, 10 WATT RESISTOR TO DISCHARGE THE CAPACITORS.

SYMPTOM: MOTOR WILL NOT START.

PROBABLE CAUSE	HOW TO DETERMINE
1. NO POWER.	1. CHECK VOLTAGE AT THE TOP TERMINAL OF THE PC CONTACTOR AND AT THE BOTTOM TERMINAL OF THE MAIN CONTACTOR. VOLTMETER SHOULD READ LINE VOLTAGE BETWEEN THESE TWO POINTS. IF VOLTAGE OK, GO TO NEXT STEP.
2. MAIN AND PC CONTACTORS NOT CLOSING	2. CHECK THE TWO 20 AMP CONTROL FUSES LOCATED ON THE CONTACTOR PANEL BOARD. IF FUSES OK, GO TO NEXT STEP.

3. Defective wiring or operating coil.	3. Check the continuity of the control circuit wiring to the main and PC contactor operating coil. This circuit includes the directional switch. If you get a reading of 0 Ohms, go to the next step.
4. Directional contactors not closing.	4. Check bottom 5 amp control fuse on contactor panel. If defective, replace fuse. If ok, check continuity of control circuit. This circuit should be complete between the fuse and the operating coils of the directional contactors. If you get a reading of 0 ohms, go to next step.
5. Defective or improperly adjusted foot switch.	5. Check continuity of foot switch (FS-1). If defective, replace. If you get a reading of 0 ohms, check adjustment of foot switch. If necessary adjust. If adjustment is ok, go on to next step.

6.	SC CONTACTOR INTERLOCK CONTACTS DEFECTIVE.	6.	VISUALLY CHECK THE POWER TIPS OF THE SC CONTACTOR. IF THEY ARE BURNED OR STUCK TOGETHER, REPLACE. IF OK, GO ON TO NEXT STEP.
7.	FLYWHEEL DIODES DEFECTIVE.	7.	CHECK RESISTANCE OF DIODES WITH OHMMETER. IF DEFECTIVE REPLACE. IF OK, CHECK SCR FUSE. IF OK, GO ON TO NEXT STEP.
8.	BLOWN SCR FUSE OR DEFECTIVE "MAIN" SCR.	8.	CHECK SCR FUSE. IF OK, CHECK "MAIN" SCR. FIRST, CHECK FOR VOLTAGE AT THE GATE. NEXT, CHECK ANODE TO CATHODE. FINALLY, CHECK GATE TO CATHODE. IF DEFECTIVE, REPLACE. IF OK, GO ON TO NEXT STEP.
9.	DEFECTIVE LOGIC BOX OR PROGRAM MODULE ON SUPPRESSION CENTER ASSEMBLY.	9.	REPLACE LOGIC BOX OR PROGRAM MODULE. IF STILL DEFECTIVE, GO ON TO NEXT STEP.
10.	DEFECTIVE MOTOR.	10.	CHECK MOTOR. IF DEFECTIVE, REPAIR OR REPLACE.

SYMPTOM: Runs Reverse, but not Forward.

Note: Follow the same procedure if motor will not run in reverse, except make all checks to the reverse contactor control circuit.

Probable Cause	How to Determine
1. Contactor tips welded together.	1. Visually check tips. If welded or stuck together, replace. If ok, go on to next step.
2. Operating coil for forward contactor is defective.	2. Check coil using an ohmmeter. If you get a reading of 0 ohms, go on to next step.
3. Defective directional switch.	3. Check continuity of the directional switch with an ohmmeter. If you get a reading of 0 ohms, go on to next step.
4. Open circuit in control wiring to forward contactor.	4. Use ohmmeter to check continuity between directional switch and operating coil and from operating coil to terminal #6 on the logic box.

SYMPTOM: MOTOR WILL NOT RUN AT FULL SPEED.

PROBABLE CAUSE	HOW TO DETERMINE
1. SC BY-PASS CONTACTOR DEFECTIVE.	1. VISUALLY CHECK TO LOOK AND SEE IF IT IS CLOSING. IF OK, CHECK SCR FUSE. IF BLOWN, REPLACE AND CHECK FLYWHEEL DIODES BEFORE ENERGIZING PANEL. IF OK, GO ON TO NEXT STEP.
2. DEFECTIVE SWITCH (FS-2) IN FOOT SWITCH OR IMPROPERLY ADJUSTED LINKAGE.	2. USE OHMMETER TO CHECK CONTINUITY OF THE (FS-2) MICRO SWITCH. IF YOU GET A READING OF 0 OHMS, CHECK LINKAGE FOR PROPER ADJUSTMENT. IF SWITCH AND LINKAGE ADJUSTMENTS ARE OK, GO ON TO NEXT STEP.
3. DEFECTIVE SC OPERATING COIL.	3. USE OHMMETER TO CHECK CONTINUITY OF COIL. IF YOU GET A READING OF 0 OHMS, GO ON TO NEXT STEP.
4. DEFECTIVE WIRING TO SC OPERATING COIL.	4. CHECK CONTINUITY BETWEEN FOOT SWITCH AND SC OPERATING COIL. CHECK CONTINUITY BETWEEN SC

	OPERATING COIL AND LOGIC UNIT TERMINAL #9. IF YOU GET A READING OF 0 OHMS, GO ON TO NEXT STEP.
5. DEFECTIVE LOGIC UNIT.	5. REPLACE LOGIC UNIT.

SYMPTOM: Motor runs but at extremely low power.

Probable Cause	How to Determine Cause
1. Shorted SCR #2.	1. Check SCR. Be sure to check Gate to Voltage, Anode to Cathode, and Gate to Cathode. If ok, go on to next step.
2. Potentiometer in foot switch defective or improperly adjusted.	2. Check with ohmmeter. Repair or replace the foot switch if necessary. If ok, go on to next step.
3. Improper current limit adjustment.	3. Check and adjust current limit. See Note below. If ok, go on to next step.
4. Defective motor.	4. Check motor.

Note: Current Limit Adjustment

Current limit adjustments cannot be made on the training panel due to limitations in the size of the power supply. For the purposes of information the procedure is as follows:

1. Disconnect the power supply.

2. Connect a D. C. ammeter or tong meter in series with one of the motor armature leads.
3. Remove the 5-amp fuse from the SC contactor control circuit.
4. Remove the rubber plug from the program module.
5. With a small screwdriver, turn the potentiometer fully clockwise or until a clicking noise is heard.
6. Connect the power supply and block the motion of the motor.
7. With the motion of the motor blocked, slowly depress the accelerator pedal.
8. Watch the ammeter. The meter should increase to between 200 and 300 amps and then remain constant when the accelerator is fully depressed.
9. With the accelerator fully depressed, turn the current-limit potentiometer counter clockwise.
10. Watch the ammeter. Continue adjustment until the current is at rated amperage.
11. Release the accelerator, replace the plug in the program module, and replace the fuse.

SYMPTOM: MOTOR STARTS TO RUN, THEN STOPS.

PROBABLE CAUSE	HOW TO DETERMINE CAUSE
1. DIRECTIONAL CONTACTORS OPENING WITH A FLASH.	1. VISUALLY CHECK CONTACTORS FOR FLASHING. IF FLASHING, GO ON TO NEXT STEP.
2. SHORTED SCR #1.	2. CHECK SCR. BE SURE TO CHECK GATE, ANODE TO CATHODE, AND GATE TO CATHODE VOLTAGE. IF OK, GO ON TO NEXT STEP.
3. SHORTED SCR #2.	3. CHECK SCR AS IN #2.
4. SHORTED SCR #3.	4. CHECK SCR AS IN #2.
5. SHORTED CAPACITOR.	5. CHECK CHARGE AND DISCHARGE OF CAPACITORS WITH OHMMETER. IF OK, GO ON TO NEXT STEP.
6. DEFECTIVE LOGIC UNIT.	6. REPLACE LOGIC UNIT.

PROBLEMS FOR STUDENT HANDOUT #1

TAKE YOUR VOM, CONTROL AND POWER CIRCUIT DIAGRAMS, AND TROUBLESHOOTING GUIDE AND GO TO THE SOLID STATE, BATTERY POWERED PANEL. DO THESE PROBLEMS.

1. CHECK THE VOLTAGE AT THE TOP TERMINAL OF THE PC CONTACTOR AND AT THE BOTTOM TERMINAL OF THE MAIN CONTACTOR.
   READING ______________

2. CHECK CONTINUITY OF FOOT SWITCH (FS-1). WHERE DID YOU ATTACH THE VOM? ____
   READING ______________

3. CHECK "MAIN" SCR.
   VOLTAGE READING AT GATE ________________
   VOLTAGE READING ANODE TO CATHODE ____________________
   VOLTAGE READING GATE TO CATHODE ____________________

4. CHECK CONTINUITY OF OPERATING COIL FOR FORWARD CONTACTOR, WHERE DID YOU ATTACH THE VOM? ________________________
   READING _____________

5. CHECK POTENTIOMETER IN FOOT SWITCH WITH OHMMETER. RECORD ANY THREE READINGS _________ _________ _________

6. CHECK ONE FLYWHEEL DIODE. RECORD BOTH READINGS.
   _____________ _____________

PROBLEM #1

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

PROBLEM: MOTOR WILL NOT START.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)
2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________
3. WHAT IS THE PROBLEM?
4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #2

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

PROBLEM: MOTOR RUNS IN REVERSE, BUT NOT FORWARD.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)
2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________
3. WHAT IS THE PROBLEM?
4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #3

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

PROBLEM: MOTOR WILL NOT RUN AT FULL SPEED.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #4

UNIT: 21 SOLID STATE, BATTERY POWERED: TROUBLESHOOTING

PROBLEM: MOTOR RUNS AT EXTREMELY LOW POWER.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #5

PROBLEM: MOTOR STARTS TO RUN, THEN STOPS.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #6

PROBLEM: MOTOR WILL NOT START.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

(A)

(B)

(C)

(D)

(E)

(F)

(G)

2. DID YOU ~~TAKE ANY METER RE~~ADINGS? RECORD THE READINGS HERE.

(A) ____________________

(B) ____________________

(C) ____________________

(D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #7

PROBLEM: MOTOR RUNS IN FORWARD, BUT NOT IN REVERSE.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #8

PROBLEM: MOTOR WILL NOT RUN AT FULL SPEED.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.
   (A)
   (B)
   (C)
   (D)
   (E)
   (F)
   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.
   (A) ____________________
   (B) ____________________
   (C) ____________________
   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #9

PROBLEM: MOTOR RUNS AT EXTREMELY LOW POWER.

ACTIVITIES:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

PROBLEM #10

Problem: MOTOR STARTS TO RUN, THEN STOPS.

Activities:

1. WRITE DOWN THE MAJOR CHECKS YOU MAKE.

   (A)

   (B)

   (C)

   (D)

   (E)

   (F)

   (G)

2. DID YOU TAKE ANY METER READINGS? RECORD THE READINGS HERE.

   (A) ____________________

   (B) ____________________

   (C) ____________________

   (D) ____________________

3. WHAT IS THE PROBLEM?

4. WHAT DID YOU DO TO CORRECT THE PROBLEM?

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